Marinus Westveld's

Empirical Yield Tables for Spruce-Fir Cut-Over Lands in the Northeast

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EMPIRICAL YIELD TABLES FOR SPRUCE-FIR CUT-OVER LANDS IN THE NORTHEAST

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INTRODUCTION

PREDICTING FUTURE TIMBER yields is an unavoidable task for the forest manager who is interested in growing timber as a long-term investment. He must predict yields as a basis for formulating management plans and policies. And he must predict yields from lands that differ greatly in productivity.

In the spruce-fir region of the Northeast the problem of predicting yields from different kinds of lands is particularly pressing. Here for years vast timberlands have been operated primarily for pulpwood. With the rapid depletion of old-growth stands, pulp mills are becoming increasingly dependent on the new stands that have become established since the clear-cutting that has been the vogue during the past half century. Some areas that were originally clear-cut have already been subjected to a second cutting; others will be ready for another harvesting within 10 or 15 years.

To manage this steadily mounting acreage of second-growth pulpwood forest intelligently, forest managers need yield tables that are applicable to these forests. The yield tables presented here were developed to fill this need. They show expected yields from stands of different compositions, ages, stocking, and site conditions.

PAST STUDIES OF SPRUCE-FIR YIELDS

Numerous studies of growth on cut-over spruce-fir lands have been made both in the Northeastern States and in eastern Canada. Most of them made use of increment borings taken from trees over a range of diameters; the data usually were classified by forest type and age of cuttings. A few studies were based on re-measurement of permanent sample plots. Results were ordinarily expressed in percentage growth figures or volume growth per acre.

Such studies have their greatest value in showing past and estimated future growth on the specific areas studied. But no systematic effort has been made to develop ways of applying such yield data to other properties.

Efforts to meet the growth problem have also been made through use of normal yield tables. Early workers in this field were Murphy (6) and Meyer (4).[1] They both conducted their studies in pure, even-aged conifer stands that contained mostly red spruce (*Picea rubens*), white spruce (*P. glauca*), and balsam fir (*Abies balsamea*).

However, spruce-fir forests of the Northeast differ notoriously from such stands. By and large they consist not of pure spruce and fir, but of mixtures of these species with varying proportions of northern hardwoods. Most of the plots Murphy and Meyer based their tables on were in pure "old-field" spruce types. Since these are among the most productive sites in the region, their tables tend to exag-

[1] Underlined numbers in parentheses refer to Literature Cited, page 53.

gerate the yields one might expect from natural forest stands. Mulloy (5), working in Canada, attempted to overcome some of the inherent weaknesses of such tables by developing a whole series of yield tables classified by forest type, composition, and density of stocking.

The heterogeneity of the northeastern spruce-fir type complicates the problem of predicting growth and yield. Hardwoods are present in varying numbers, sizes, species, and spacing. The spruce-fir component, though usually small in volume after clear-cutting, nevertheless has a wide range in both size and number of trees; and advance spruce-fir reproduction, the mainstay for the next timber crop, varies greatly in stocking.

With this situation in mind, the author (8) undertook to develop a predicting method that could be applied satisfactorily to the irregular mixed spruce-hardwood stands so common to the spruce-fir region of the Northeast.

The complexity of the problem, however, necessitated the introduction of new statistical procedures. The methods Westveld used and the yield tables evolved were described in 1941 (8). But these tables, like their predecessors, were not entirely free of weaknesses. One of the most serious was a failure to take into account changes in stand density with passage of time. Fortunately a reasonably accurate measure of this increase has since been obtained through further studies and repeat measurements on approximately 28 percent of the original growth plots that were used in the yield study.

(It is appropriate to mention here the comprehensive growth study recently begun by a group of Maine timberland owners in cooperation with the Northeastern Forest Experiment Station. This study consists of a network of permanent plots set up in a distribution pattern calculated to produce reliable growth estimates for all stand conditions. However, under this continuous-inventory system at least one--and preferably two--growth periods must elapse before a sound basis for growth predictions will be available.)

The empirical yield tables presented here were designed to serve until more reliable data become available.

BASIS FOR THIS STUDY

The yield tables developed in this study are based on 365 plots established throughout the spruce-fir region of the northeastern United States (fig. 1). The plots were located in representative stands scattered from northernmost Maine to the Adirondacks of New York, including the White and Green Mountain regions of New Hampshire and Vermont.

The plots were confined to those forest sites known as lower spruce slopes and spruce and balsam flats. These are the sites that contain the bulk of the spruce-fir growing stock held by timberland owners of the region. A total of 207 plots were set up in the dominant softwood types (spruce and fir flats where spruce and fir made up 70 percent or more of the stand). The other 158 plots were in the secondary softwood types (lower spruce slopes where hardwood representation ranged from 25 to 70 percent).

A systematic scheme of plot selection was followed so as to sample the widest possible variety of cut-over land conditions and to assure that final results would express the general conditions of the region. Ages of cutting areas studied ranged from those recently cut to those cut 60 years previously (table 1). On most of these areas clear-cutting of conifer pulpwood species had been practiced; that is, spruce and fir down to 6 or 8 inches d.b.h. had been removed while the hardwoods had been left. Thus the residual stands consisted mainly of unmerchantable-size spruce-fir stems

Table 1.--Distribution of yield-study plots by site class, locality, and years since cutting

(In number of plots)

Years since cutting	Dominant softwood sites					Secondary softwood sites					All sites
	Me.	N.H.	Vt.	N.Y.	Total	Me.	N.H.	Vt.	N.Y.	Total	
Less than 3	10	--	--	--	10	8	--	--	1	9	19
3- 7	12	--	--	--	12	--	15	2	--	17	29
8-12	27	23	--	--	50	19	21	6	6	52	102
13-17	6	4	--	4	14	--	3	7	8	18	32
18-22	24	--	--	8	32	--	3	7	--	10	42
23-27	15	--	--	15	30	--	12	--	--	12	42
28-32	13	--	--	16	29	--	--	3	21	24	53
33-37	3	--	--	--	3	--	4	--	2	6	9
38-42	5	6	--	--	11	--	6	2	--	8	19
43-45	6	--	--	--	6	2	--	--	--	2	8
47-52	4	4	--	--	8	--	--	--	--	--	8
55-57	--	--	--	--	--	--	--	--	--	--	--
58-62	2	--	--	--	2	--	--	--	--	--	2
Total	127	37	--	43	207	29	64	27	38	158	365

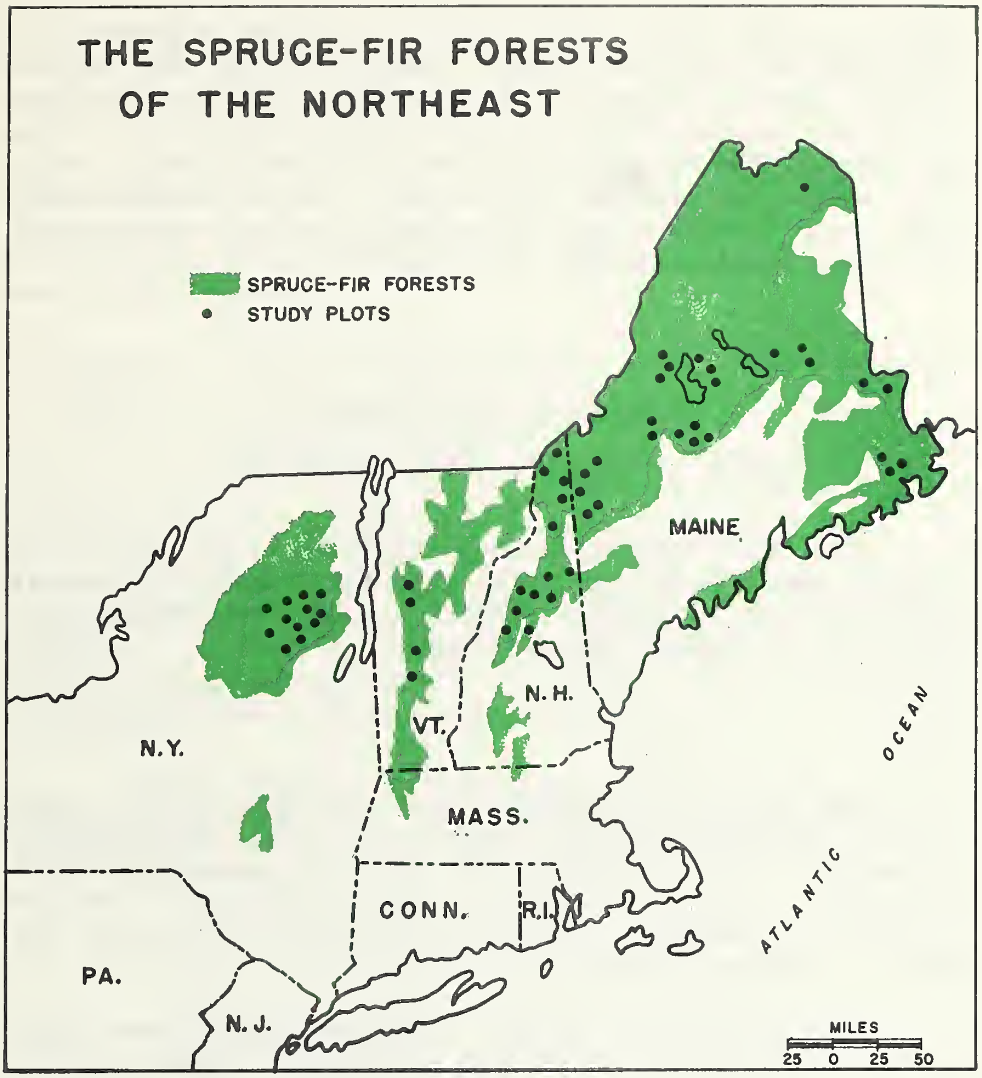

FIGURE 1.--The spruce-fir forests of the Northeast and the general distribution of the 365 study plots used in developing the yield tables.

plus hardwoods ranging from small trees to mature trees of large size.

Repeat measurements have been made on 91 plots (approximately 25 percent of the 365 plots). The first re-measurements were made 5 to 8 years after plot establishment (in 1924 and 1925). Re-measurements were made at 5-year

intervals after that. Since the first re-measurements, 18 plots (about 21 percent) have been abandoned for various reasons, leaving 39 plots on the dominant softwood sites and 34 on the secondary sites on which re-measurements are being continued. The re-measurement data provided a fairly reliable basis for testing the accuracy of the yield tables developed. At the same time they provided a measure of changes in composition and stand density.

GROWTH FACTORS AND THEIR EVALUATION

In stands as complex as those found in the spruce-fir region, numerous factors influence the growth and yield of the spruce-fir component. Those exerting the strongest influence were selected for analysis.

Site

The factors that make up site, or site quality, have a strong influence not only on the growth rate of spruce and balsam fir but also on the extent of their representation in the stand. The more favorable these site factors are for spruce-fir production, the greater will be (normally) the yield of these species.

In the spruce-fir region site quality and forest type are closely related. They are determined largely by the physical character of the soil, as affected by drainage. The shallow soils and the soils with poor drainage normally offer the poorest sites. Best sites occur on well-drained, aerated soils of good depth. It is on the wet, shallow soils of the bottom lands and the droughty soils of steep mountain slopes, however, that spruce and fir occur in the greatest abundance. Both species possess root systems well adapted to such sites. Pure spruce-fir stands are almost limited to them.

Hardwoods, on the other hand, require deep fertile soils that offer no serious obstacle to deep root penetration. On the best of these soils hardwoods establish themselves in large numbers and show excellent development. On

such sites the faster-growing, more aggressive hardwoods relegate spruce and fir to secondary and often minor importance. In soils of medium quality, conifers and hardwoods strive with nearly equal success for supremacy of the site.

To give recognition in a broad way to the factor of site, the data were treated on the basis of the two broad site groupings: (1) dominant softwood sites and (2) secondary softwood sites. All plots were segregated into these two classifications.

Dominant softwood sites

Dominant softwood sites are readily recognized by the preponderance of softwood species and the general absence of sugar maple (Acer saccharophorum) and beech (Fagus grandifolia) in the hardwood component (fig. 2). Red spruce and balsam fir are the principal species; hemlock (Tsuga canadensis) and white pine (Pinus strobus) are common associates. Hardwoods are mainly yellow birch (Betula lutea), paper birch (B. papyrifera), aspen (Populus tremuloides), and red maple (Acer rubrum). In the low, wet, and swampy areas black spruce (Picea mariana) predominates. Northern white-cedar (Thuja occidentalis) and tamarack (Larix laricina) are also common.

These softwood sites occur under a wide range of topographic conditions, on steep mountain slopes from about 3,000 feet elevation to timber line as well as in the more

Table 2.—Spruce-fir site-types of the Northeast, ranked by fertility

Type name: Local	Type name: Society of American Foresters	Site class	Place in succession
1. Old-field	Red spruce	Dominant	Usually subclimax to red spruce-sugar maple-beech or red spruce-yellow birch
2. Lower spruce slope	Red spruce-sugar maple beech	Secondary	Climax
	Red spruce-yellow birch	Secondary	Possibly climax
	Red spruce-yellow birch	Dominant	Possibly climax
3. Spruce flat and balsam flat	Paper birch-red spruce-balsam fir	Dominant	Subclimax to red spruce or red spruce-yellow birch
	Red spruce	Dominant	Climax
	Balsam fir	Dominant	Subclimax to red spruce
4. Upper spruce slope	Red spruce	Dominant	Climax
5. Spruce swamp	Black spruce	Dominant	Climax


A

FIGURE 2.--Dominant softwood sites. Most dominant softwood stands, such as A (left), contain an admixture of hardwoods, principally birch and red maple.

Stand B (above) consists mostly of red spruce, with a scattering of balsam fir and white pine.

The ground cover on these dominant softwood sites is mainly low-growing herbs, mosses, and ferns, with occasional low shrubs.

gentle topography found on bench lands that reach back from streams and lakes and on poorly drained bottom lands and swamps.

Low ground vegetation characterizes these sites. In the nearly pure conifer type feather mosses (mainly Hylocomium), ferns, and numerous herbs comprise the principal ground cover. Common herbaceous plants are bunchberry (Cornus canadensis), woodsorrel (Oxalis acetosella), Canadian mayflower (Maianthemum canadense), and red raspberry (Rubus idaeus). Occasional dwarf shrubs such as lowbush blueberry (Vaccinium angustifolium), Labrador tea (Ledum groenlandicum), and sheep laurel (Kalmia angustifolia) may be present, particularly on areas with slow drainage. With an increased representation of hardwoods, taller shrubs such as witch hobble (Viburnum alnifolium) and honeysuckle (Lonicera canadensis) replace to some extent the dwarf shrubs and herbaceous growth. Where the hardwood admixture includes some beech, scattered mountain maple (Acer spicatum) and striped maple (A. pensylvanicum) may also be found.

Secondary softwood sites These sites may be recognized by the presence of beech, sugar maple, and yellow birch in varying proportions in mixture with red spruce (fig. 3). Balsam fir is also present but usually in lesser numbers than spruce. Hemlock is another common softwood associate. Northern hardwoods comprise 25 to 70 percent of the stand. Secondary softwood sites occupy the better-drained soils of the lower mountain slopes and ridge lands of medium elevation.

Low ground vegetation on these sites is more scanty than on the dominant softwood sites, while shrub growth and hardwood reproduction assume more importance. Nevertheless, herbaceous plants also occur here, some of which--like wood sorrel and Canadian mayflower--are also common to the dominant softwood sites.

Other plants that help to identify these sites are the shiny clubmoss (Lycopodium lucidulum), clintonia (Clintonia borealis), and twisted stalk (Streptopus roseus). Prominent among the shrubs are witch hobble, ground hemlock (Taxus canadensis), and honeysuckle. Striped maple and mountain maple occur with greater frequency; and hardwood reproduction, largely sugar maple and beech, makes up a large part of the low vegetation.

Density

Density is another important factor that affects the yield from forest stands, an increase in density normally being accompanied by an increase in yield. Under the favorable growing conditions that prevail in the Northeast, old-growth spruce-fir stands as a whole contain a full stocking of reproduction prior to cutting. Yet an analysis of stand data obtained in connection with the growth-and-yield study

Table 3.—Stand table[1] by species and diameter class, in number of trees per acre

Diameter class (inches)	Red spruce	Balsam fir	Yellow birch	Beech	Sugar maple	Red maple	Paper birch	Miscellaneous	Total spruce and fir	All merchantable hardwoods	All weed species
DOMINANT SOFTWOOD SITES											
1	18.9	34.7	5.7	0.6	0.1	5.9	9.2	2.2	53.6	23.7	0.6
2	16.4	16.2	3.5	.6	—	2.1	2.1	1.8	32.6	10.1	1.3
3	10.4	10.0	3.3	.5	—	1.2	1.4	2.5	20.4	8.9	.7
4	8.3	6.5	2.8	.5	—	1.0	1.0	1.8	14.8	7.1	.7
5	5.5	4.5	2.4	.2	—	1.1	1.4	1.5	10.0	6.6	.1
6	3.7	2.7	2.8	.4	—	.9	1.0	1.2	6.4	6.3	.1
7	3.8	2.0	2.6	.4	—	.8	1.2	.7	5.8	5.7	.3
8	5.3	1.5	2.7	.3	—	.7	1.0	.7	6.8	5.4	—
9	2.2	.6	1.6	.2	—	.8	.8	.6	2.8	4.0	—
10	1.0	.6	3.4	.2	.1	.5	.7	.8	1.6	5.6	—
11	.7	.3	1.8	.2	—	.3	.6	.6	1.0	3.6	—
12	.2	.1	1.2	—	—	.3	.5	.8	.3	2.8	—
13	.2	.1	1.0	—	—	.1	.4	.3	.3	1.8	—
14	—	—	.9	—	—	.2	.3	.3	—	1.7	—
15	—	—	.5	—	—	.1	.2	.2	—	1.0	—
16	—	—	.6	—	—	—	.1	.2	—	.9	—
17	—	—	.5	—	—	—	.2	—	—	.7	—
18	—	—	.2	—	—	—	—	—	—	.2	—
19	—	—	.1	—	—	—	—	—	—	.1	—
20	—	—	.1	—	—	—	—	—	—	.1	—
21	—	—	.1	—	—	—	—	—	—	.1	—
Total	76.6	79.8	37.8	4.1	.2	16.0	22.1	16.2	156.4	96.4	3.8
Percentage	29.8	31.1	14.8	1.6	.1	6.2	8.6	6.3	60.9	37.6	1.5
SECONDARY SOFTWOOD SITES											
1	13.8	5.8	11.6	5.2	4.0	4.9	3.6	0.4	19.6	29.7	1.5
2	9.2	7.8	8.3	3.9	2.1	3.8	1.3	.4	17.0	19.8	5.0
3	6.8	6.2	3.4	1.4	.6	.4	.2	.3	13.0	6.3	1.9
4	5.4	3.1	4.9	2.3	1.2	3.6	.3	.5	8.5	12.8	.9
5	4.7	1.8	3.0	1.6	.5	.4	.2	—	6.5	5.7	—
6	2.1	1.0	3.3	2.6	.4	.9	.3	.5	3.1	8.0	.2
7	3.0	.6	1.6	1.0	.6	.3	.4	.1	3.6	4.0	—
8	1.4	.1	3.3	1.8	.3	.8	—	—	1.5	6.2	—
9	.5	.1	1.4	1.2	—	.3	.4	.1	.6	3.4	—
10	.2	—	2.3	1.8	.4	.8	—	.1	.2	5.4	—
11	.2	—	1.1	1.2	—	.1	—	—	.2	2.4	—
12	.2	—	2.4	1.2	.4	.5	—	—	.2	4.5	—
13	—	—	.6	.7	.3	—	—	—	—	1.6	—
14	—	—	1.2	.7	.6	—	—	—	—	2.5	—
15	—	—	.4	.2	.3	—	—	—	—	.9	—
16	—	—	1.0	.6	.3	.3	—	.1	—	2.3	—
17	—	—	.6	.1	—	.3	—	—	—	1.0	—
18	—	—	.8	.1	—	—	—	—	—	.9	—
19	—	—	.1	—	—	—	—	—	—	.1	—
20	—	—	.4	—	—	—	—	—	—	.4	—
22	—	—	.3	—	—	—	—	—	—	.3	—
Total	47.5	26.5	52.0	27.6	12.0	17.4	6.7	2.5	74.0	118.2	9.5
Percentage	23.6	13.1	25.8	13.7	6.0	8.6	3.3	1.2	36.7	58.6	4.7

[1] Residual stand after cutting to small diameters for spruce and balsam fir only.

FIGURE 3.--Examples of secondary softwood sites. In these stands spruce and balsam fir occur in mixture with beech, yellow birch, and sugar maple.

A (above) is an uncut stand. In B (right) the merchantable-size softwoods have been cut, leaving hardwoods to dominate the stand.

The ground vegetation on these secondary softwood sites is witch hobble and hardwood reproduction and a variety of herbaceous plants.

shows that cutting leaves these lands in greatly varying states of stocking (table 3).

Several factors prevent adequately stocked stands of reproduction from developing into fully stocked stands of pulpwood. Among them are damage to young growth through careless logging, smothering of reproduction by the accumulation of slash from clear-cutting, elimination of valuable species through competition from inferior species, and fire --which has run over extensive areas of cut-over land. In many places poor stocking can be attributed to lack of advance reproduction before logging.

Relative-density concept Of a group of stands that have the same average diameter, the one that has the greatest number of trees is the best stocked--the densest--of the group. To express stand density adequately, a modification of the method developed by

Reineke (7) was used. The term "relative density", as used here, is the percentage relationship between the number of trees per acre for a specific stand and the regional average number of trees for the same average diameter.

The average number of trees per acre for different average diameters for empirically stocked stands may be considered as representing 100 percent. Then the relative density of an individual stand is its number of trees expressed as a percentage of the tabular values for the same diameter. This contrasts with Reineke's stand-density-index concept, which shows the progression of number of trees and diameters under conditions of uniform stocking.

Change in stand density

As indicated earlier, some information on the rate at which density changes has been obtained since publication of the original empirical yield tables for spruce-fir. These changes are highly significant (table 4).

Table 4.--Average change in composition and density over a 15-year period[1]

Site-type	Composition index			Density index			Average age of cuttings		Basis: Number of plots
	1925	1940	Increase or decrease	1925	1940	Increase or decrease	1925	1940	
Dominant softwood	68	69	+1	106	131	+25	24	39	39
Secondary softwood	53	49	-4	104	154	+50	18	33	34

[1]Composition changes to be significant at the 1-percent level must exceed 7 units for the dominant sites and 15 for the secondary sites; at the 5-percent level the corresponding figures are 5 and 11.

Density changes to be significant at the 1-percent level must exceed 13 units for the dominant sites and 18 for the secondary sites; at the 5-percent level the corresponding figures are 9 and 13.

Analysis of the data showed that density increases rapidly in areas cut recently, as new reproduction comes in. As time passes, the increase in density tapers off; and, as the stand becomes mature and mortality sets in, density begins to decrease. Thus allowance must be made for density changes. Otherwise there is danger of underestimating yield from young stands and overestimating yield from old stands.

The same trend in density is manifested in degree of stocking. Rapid increase in density is associated with low

initial stocking. The rate declines as the stocking increases, actual reduction in density occurring in older stands that have a high density of stocking.

Some idea of how changes in density affect growth and yield can be gained from table 5, in which a 20-year-old cut-over area (dominant site) with a composition index of 70 is used as an example. In this example, errors in yield estimates range up to 11.3 percent and those for growth up to 26.9 percent.

Table 5.--Comparison of growth and yield over a 10-year period with and without allowance for density changes

(For 20-year old spruce-fir stand on the dominant softwood site with a composition index of 70.)

Density at beginning of 10-year period	Assuming no density change			Allowing for density change					
	Volume at--		Growth for 10-year period	Density at end of period	Change in density	Volume at end of period	Growth for 10-year period	Error in growth estimate	Error in yield estimate
	Beginning of period	End of period							
Units	Cords	Cords	Cords	Units	Units	Cords	Cords	Percent	Percent
30	3.2	5.1	1.9	64	+34	5.7	2.5	24.0	10.5
50	3.6	5.5	1.9	83	+33	6.2	2.6	26.9	11.3
70	3.9	6.0	2.1	102	+32	6.6	2.7	22.2	9.1
90	4.3	6.4	2.1	120	+30	7.0	2.7	22.2	8.6
110	4.7	6.8	2.1	138	+28	7.4	2.7	22.2	8.1
130	5.1	7.2	2.1	154	+24	7.8	2.7	22.2	7.7
150	5.5	7.7	2.2	170	+20	8.1	2.6	15.4	4.9
170	5.9	8.1	2.2	185	+15	8.4	2.5	12.0	3.6
190	6.3	8.5	2.2	200	+10	8.7	2.4	8.3	2.3
210	6.7	9.0	2.3	215	+ 5	9.1	2.4	4.2	1.1

Composition

Growth and yield of spruce and fir are closely related to stand composition. As pointed out earlier, the two broad site-type groups used in the yield study contain extremely complex and variable mixtures of both hardwoods and softwoods. So the extent to which spruce and fir are in possession of an area will largely determine the final yields of these species.

Composition index In view of the importance of composition, it was necessary to evolve a scheme for measuring and classifying the wide range of stand composition encountered in the study. The simple scheme evolved is based on the relationship of the number of spruce

FIGURE 4.--Other things being equal, the greater the elapsed time since cutting, the greater the yield. Stand A (above) is in a 10-year-old cutting; young softwoods are in complete possession of the stand but only few are of pulpwood size.

Stand B (right) was cut for pulpwood 30-35 years ago, and now it supports more than 10 cords of spruce-fir per acre. Both are classed as dominant softwood stands.

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Unite	Cords	Cords	Cords	Units	Units	Cords	Cords	Perceht	Percent
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50	3.6	5.5	1.9	83	+33	6.2	2.6	26.9	11.3
70	3.9	6.0	2.1	102	+32	6.6	2.7	22.2	9.1
90	4.3	6.4	2.1	120	+30	7.0	2.7	22.2	8.6
110	4.7	6.8	2.1	138	+28	7.4	2.7	22.2	8.1
130	5.1	7.2	2.1	154	+24	7.8	2.7	22.2	7.7
150	5.5	7.7	2.2	170	+20	8.1	2.6	15.4	4.9
170	5.9	8.1	2.2	185	+15	8.4	2.5	12.0	3.6
190	6.3	8.5	2.2	200	+10	8.7	2.4	8.3	2.3
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In view of the importance of composition, it was necessary to evolve a scheme for measuring and classifying the wide range of stand composition encountered in the study. The simple scheme evolved is based on the relationship of the number of spruce

FIGURE 4.--Other things being equal, the greater the elapsed time since cutting, the greater the yield. Stand A (above) is in a 10-year-old cutting; young softwoods are in complete possession of the stand but only few are of pulpwood size.

Stand B (right) was cut for pulpwood 30-35 years ago, and now it supports more than 10 cords of spruce-fir per acre. Both are classed as dominant softwood stands.


B

and balsam fir trees to the total number of all trees in the stand.

This measure of spruce-fir representation in the stand was termed the "composition index". Thus a stand that contains spruce and fir only rates a composition index of 100; a stand with half its trees spruce and fir rates an index of 50, and so on.

Changes in composition Because spruce-fir yields are closely correlated with changes in composition, the extent of such changes was studied. Data from re-measurements of the original growth-study plots were used. The study showed (table 4) that changes in composition are not significant.

Apparently under normal conditions the relationships between hardwoods and softwoods are maintained or are only slightly altered over a long period. Of course an epidemic of disease or insects could quickly disturb this balance.

Elapsed Time Since Cutting

Other things being equal, the greater the elapsed time since cutting, the greater will be the yield (fig. 4). Often maps or office records will reveal the date of cutting for the different parcels of land in an ownership block.

If such information is not available, it can be obtained during the inventory cruise. Date of cutting can usually be determined within a year or two by counting the annual growth rings on fast-growing hardwoods that spring up in skid roads and skid trails the first growing season after logging. Increment borings will often provide another clue to date of cutting: well-developed trees near stumps usually show accelerated growth as a result of the cutting.

Effective Age

However, even among stands of identical age, growing-stock volume varies greatly (table 6). For example, among plots comprising the 20-year-old cutting series the volume deviation ranges from 6.8 to 60.4 percent of mean.

This is understandable when one considers the wide range in stand conditions that result from pulpwood cutting operations. Cutting leaves some areas practically devoid of trees; even seedlings may be lacking (fig. 5). Other areas, even after clear-cutting, are left with a good stocking of reproduction and saplings up to 5 inches d.b.h. as well as a scattering of merchantable size trees skipped by the cutters. The average recently cut-over area is likely to support a stand midway between these two extremes.

Table 6.--Volume deviations from the mean: comparison of effective and chronological ages of 20-year-old cuttings on dominant softwood site

Plot number	Composition index	Density index	Actual volume per acre	Deviation from mean	Chronological age	Effective age
	Units	Units	Cu.ft.	Percent	Years	Years
28	50	82	356	-38.0	20	22
29	53	97	353	-38.5	20	20
30	50	104	256	-55.4	20	14
31	76	90	720	+25.3	20	33
32	77	85	749	+30.4	20	35
33	78	83	613	+ 6.8	20	30
34	69	111	626	+ 9.0	20	30
35	78	85	921	+60.4	20	44
Mean	66	92	574	0	20	28

By determining the "effective age" of a stand it is possible to adjust for these differences. In calculating yield, "effective age" was used rather than age of cutting. "Effective age" functions as an indirect expression of growing-stock volume.

It is obvious that after a lapse of 20 years the yield from a well-stocked cut-over area will be much greater than that from an area left devoid of trees or stocked only with seedlings. This could hardly be otherwise in view of the larger volume left as a growing base. In fact, the behavior (rate of wood production) of the well-stocked cut-over area at 20 years may be equal to that of the average 30-year-old cut-over area. If so, its "effective age" is considered to be 30 years; and this age--rather than its chronological age of 20 years--should be used in calculating yield.

FIGURE 5.--The amount of growing stock left after cutting varies greatly. Some areas are left practically devoid of trees, as in A (above). Others, even after clear-cutting, are left with a good stock of saplings, as in B (right).

After a lapse of years, the yield from the better-stocked area will obviously be greater than that from areas left devoid of trees.

Stand A is classified as dominant softwood. Stand B is secondary softwood.

On the other hand, the performance of the poorly stocked area at 20 years may resemble that of the average 10-year-old cut-over area, in which case its "effective age" is 10 years.

The inventory cruise, besides providing the data needed for computing density, composition, and years since cutting, gives the present volume of growing stock--hence the basis for determining the stand's effective age. This value[2] is obtained from the regression equation, using the

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[2]ESTIMATING THE VALUE OF THE INDEPENDENT VARIABLE FROM A KNOWN VALUE OF THE DEPENDENT MAY RESULT IN A BIASED ESTIMATE. TESTS FOR BIAS OR OTHER FLAWS WERE MADE. SO FAR AS MEAN RESIDUALS ARE CONCERNED, NO BIAS WAS FOUND IN THE REGRESSION OF EFFECTIVE AGE OVER ACTUAL AGE FOR THE DOMINANT SOFTWOOD SITES. FOR SECONDARY SOFTWOOD SITES, b WAS FOUND TO BE SIGNIFICANTLY GREATER THAN 1. BUT THIS ONLY CASTS DOUBT ON THE ESTIMATE OF EFFECTIVE AGE. THE ESTIMATE OF GROWTH MAY BE UNBIASED.

observed values of yield or growing-stock volume, density, and composition.

As employed here, the use of effective age is only an artifice to permit an approximate adjustment for present volume. To estimate future yield (later discussed in detail) it is necessary to add the desired time interval, adjust for corresponding average change in density, and substitute these values together with observed composition in the basic equation. The result is a more accurate estimate than would be obtained from conventional use of the equation because additional information is used.

A stand's effective age usually differs from its chronological age. Note (table 6) that of the eight plots in the 20-year cutting series, chronological and effective age are on a parity in only one (plot 29). In only one (plot 30) is the effective age (14 years) below the chronological age (20 years). For the majority of the plots the effective age exceeds the chronological age by a large margin. In fact the group of plots as a whole are performing in the manner of 28-year-old cut-over areas.

Cut-over areas that rate minus effective age contain few if any merchantable-size spruce and fir stems. Even though such areas are well stocked with seedlings they will still rate a low density index, because density is based only on trees 1 inch d.b.h. and larger. On these seedling-stocked areas there may be no measurable density increase for a long time. Eventually, however, as restocking progresses and reproduction attains sapling and pole size, the areas will pass from a minus to a plus effective age. From this point on, the density index may rise rapidly.

DEVELOPING THE YIELD TABLES

The most important factors that affect the growth and yield of spruce and balsam fir after clear-cutting are site, elapsed time since cutting, stand density, and stand composition. The first of these factors, site, was recognized by treating the data on the basis of two broad site groups, dominant softwood sites and secondary softwood sites. Thus elapsed time, density, and composition remained as three independent variables; and they lended themselves readily to evaluation.

To measure accurately the combined influence of these variables on yield, the standard multiple-correlation method of analysis was used. Although a straight-line regression appeared to express satisfactorily the relationships among the variables in both major site groups, evidence of some curvilinearity was found, particularly for the secondary softwoods. This curvilinearity was incorporated into the graphed equation through analysis of residuals.

Satisfactory regression curves were evolved through successive approximations. The second and final estimate for dominant softwood sites resulted in a correlation coefficient of 0.755 and a standard error of $\pm$ 446.00. The third and final estimate for secondary softwood sites gave corresponding values of 0.721 and $\pm$ 267.82.

The basic formula developed for expressing yield is--

$$V = b_1T + \frac{b_2\ (N_c + N_o)}{N} + \frac{b_3N_c}{N_c + N_o} + d$$

--in which V = volume of spruce and balsam fir; T = time since cutting; N_c = number of spruce and balsam fir trees; N_o = number of other species; N = number of trees, taken from density curve; and b_1, b_2, b_3, and d = constants.

Multiple regression equations, one for each of the two major spruce-fir type groups, were evolved. For dominant softwood sites--

$$V = 27.59T + 2.71D + 6.43C - 488.06$$

and for secondary softwood sites--

$$V = 14.55T + 3.87D + 4.02C - 269.40$$

--in which V = total cubic-foot volume of spruce and fir 1 inch d.b.h. or larger; T = time in years since cutting; D = density index; and C = composition index.

Using as a basis the final regression curves evolved for the two broad site groups, alinement charts (pp. 38-41) were constructed for each according to the method described by Bruce (2) and Reineke (3). Basic cubic-foot yield tables were calculated directly from these charts.

However, since the equations give values for the entire spruce-fir stand (that is, for all trees of these two species in and above the 1-inch diameter class), conversion factors were used to calculate merchantable yields in cubic feet and cords per acre. Behre's form-class system (1) was followed in developing the yield tables.

As developed, the empirical yield tables show the merchantable contents per acre of all spruce and balsam fir trees in and above the 6-inch diameter class, with a 1-foot stump allowance and a top utilization limit of 3 inches inside bark. No allowance was made for cull.

Two sets of tables were prepared. One shows merchantable cubic-foot volume, the other volume in cords.

Cord volumes are based on 95 cubic feet of solid wood (peeled) in a stacked cord of 128 cubic feet. Studies have shown that spruce and fir pulpwood with bark averages about 12 percent more volume than peeled pulpwood. Because unpeeled wood makes looser stacks, an over-run of approximately 15 percent should be allowed in calculating the solid content in stacked cords of unpeeled wood.

II

THE YIELD TABLES AND ALINEMENT CHARTS

I

Dominant softwood sites: Total merchantable volume per acre of all trees in 6-inch diameter class and larger

(In cubic feet)

10-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	--	--	2	24	50	79	110	143	179	217
30	--	--	21	45	74	105	137	173	211	251
50	20	26	42	69	100	133	168	205	245	286
70	24	37	65	94	127	163	200	238	279	321
90	33	60	90	122	156	194	232	273	315	357
110	56	84	117	150	187	227	266	308	349	392
130	80	111	146	182	220	260	301	343	386	427
150	107	141	176	213	254	294	336	378	422	466
170	135	170	207	247	288	330	371	414	459	504
190	165	202	241	281	324	365	408	452	497	543
210	196	235	275	316	358	401	446	490	536	583
230	228	269	310	352	395	438	483	529	576	622
250	263	303	344	387	432	476	523	569	616	663
20-YEAR-OLD CUTTINGS										
10	58	87	119	153	190	229	270	310	351	395
30	82	114	148	185	222	264	304	346	387	433
50	107	143	179	217	255	298	339	382	425	471
70	137	172	212	251	290	333	374	418	463	509
90	166	204	244	285	326	367	411	455	501	547
110	197	237	278	320	362	404	448	493	539	586
130	229	272	313	355	397	441	485	532	578	625
150	264	307	348	391	434	479	522	571	618	664
170	300	342	383	427	472	517	562	610	658	704
190	336	377	419	465	511	555	601	650	698	746
210	371	412	457	503	549	594	640	690	739	788
230	407	450	494	542	589	634	682	732	781	831
250	444	490	536	582	632	675	725	775	824	876

Dominant softwood sites, cubic-foot volume (continued).--

30-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	202	242	282	323	363	407	450	495	541	589
30	236	274	316	357	398	444	488	535	580	627
50	269	308	351	393	435	482	527	574	622	668
70	304	343	387	429	474	518	567	615	662	708
90	338	379	424	467	513	557	606	654	702	748
110	374	416	462	505	552	598	645	694	743	790
130	411	453	499	545	593	638	685	736	784	834
150	447	492	537	583	632	678	727	778	828	876
170	484	529	577	623	672	719	769	822	873	919
190	523	568	617	663	712	762	812	864	915	962
210	563	608	657	704	753	803	855	908	958	1,004
230	603	649	698	746	797	847	899	951	1,003	1,047
250	643	689	738	788	840	892	943	997	1,047	1,090
40-YEAR-OLD CUTTINGS										
10	375	420	465	510	556	602	650	698	746	795
30	412	457	502	549	595	642	690	739	788	838
50	450	495	541	587	635	682	732	781	830	882
70	488	534	580	627	676	724	774	824	874	925
90	527	573	620	668	717	766	816	867	917	970
110	566	613	660	708	757	808	859	910	961	1,015
130	606	653	700	750	800	852	902	954	1,004	1,058
150	646	693	742	792	843	894	946	999	1,049	1,102
170	686	735	784	836	885	938	989	1,042	1,094	1,147
190	727	777	827	879	928	983	1,033	1,087	1,139	1,192
210	769	821	869	922	974	1,026	1,078	1,131	1,184	1,237
230	812	864	914	967	1,018	1,069	1,123	1,177	1,231	1,285
250	856	910	958	1,011	1,062	1,114	1,169	1,222	1,277	1,334

(Continued)

Dominant softwood sites, cubic-foot volume (continued).--

50-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	570	616	663	710	760	810	862	913	966	1,018
30	610	656	703	753	802	853	906	958	1,011	1,062
50	650	696	744	795	845	897	950	1,002	1,054	1,107
70	688	737	786	838	889	942	994	1,046	1,098	1,153
90	729	778	830	883	932	985	1,038	1,090	1,143	1,197
110	772	823	873	925	976	1,029	1,082	1,135	1,187	1,243
130	814	864	917	969	1,021	1,073	1,127	1,180	1,233	1,288
150	857	908	960	1,013	1,064	1,115	1,171	1,226	1,281	1,336
170	900	953	1,003	1,056	1,108	1,162	1,217	1,273	1,328	1,384
190	944	997	1,047	1,101	1,153	1,207	1,263	1,320	1,376	1,432
210	988	1,040	1,091	1,146	1,198	1,254	1,310	1,367	1,424	1,481
230	1,032	1,084	1,136	1,191	1,244	1,300	1,358	1,414	1,471	1,528
250	1,076	1,128	1,183	1,240	1,290	1,350	1,405	1,461	1,518	1,576
60-YEAR-OLD CUTTINGS										
10	776	826	876	928	979	1,030	1,085	1,137	1,191	1,245
30	818	868	920	972	1,024	1,077	1,130	1,183	1,238	1,292
50	862	913	964	1,017	1,069	1,121	1,176	1,229	1,285	1,339
70	905	956	1,008	1,059	1,113	1,166	1,223	1,276	1,336	1,387
90	948	1,000	1,052	1,104	1,158	1,212	1,268	1,323	1,380	1,434
110	992	1,043	1,097	1,150	1,204	1,259	1,315	1,370	1,427	1,483
130	1,035	1,087	1,140	1,196	1,250	1,305	1,362	1,417	1,474	1,531
150	1,080	1,132	1,186	1,242	1,297	1,354	1,409	1,465	1,521	1,580
170	1,124	1,179	1,233	1,289	1,345	1,401	1,457	1,513	1,568	1,626
190	1,171	1,225	1,280	1,337	1,392	1,449	1,505	1,561	1,615	1,673
210	1,216	1,271	1,326	1,383	1,440	1,496	1,553	1,607	1,663	1,721
230	1,262	1,318	1,374	1,432	1,487	1,544	1,600	1,656	1,709	1,768
250	1,311	1,365	1,423	1,478	1,535	1,591	1,649	1,702	1,758	1,817

I I

Dominant softwood sites: Total merchantable volume per acre of all trees in 6-inch diameter class and larger

(In cords)

10-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	--	--	0.02	0.3	0.5	0.8	1.2	1.5	1.9	2.3
30	--	--	.2	.5	.8	1.1	1.4	1.8	2.2	2.6
50	0.04	0.2	.4	.7	1.1	1.4	1.8	2.2	2.6	3.0
70	.2	.4	.7	1.0	1.3	1.7	2.1	2.5	2.9	3.4
90	.3	.6	.9	1.3	1.6	2.0	2.4	2.9	3.3	3.8
110	.6	.9	1.2	1.6	2.0	2.4	2.8	3.2	3.7	4.1
130	.8	1.2	1.5	1.9	2.3	2.7	3.2	3.6	4.1	4.5
150	1.1	1.5	1.9	2.2	2.7	3.1	3.5	4.0	4.4	4.9
170	1.4	1.8	2.2	2.6	3.0	3.5	3.9	4.4	4.8	5.3
190	1.7	2.1	2.5	3.0	3.4	3.8	4.3	4.8	5.2	5.7
210	2.1	2.5	2.9	3.3	3.8	4.2	4.7	5.2	5.6	6.1
230	2.4	2.8	3.3	3.7	4.2	4.6	5.1	5.6	6.1	6.5
250	2.8	3.2	3.6	4.1	4.5	5.0	5.5	6.0	6.5	7.0
20-YEAR-OLD CUTTINGS										
10	0.6	0.9	1.3	1.6	2.0	2.4	2.8	3.3	3.7	4.2
30	.9	1.2	1.6	1.9	2.3	2.8	3.2	3.6	4.1	4.6
50	1.1	1.5	1.9	2.3	2.7	3.1	3.6	4.0	4.5	5.0
70	1.4	1.8	2.2	2.6	3.1	3.5	3.9	4.4	4.9	5.4
90	1.7	2.1	2.6	3.0	3.4	3.9	4.3	4.8	5.3	5.8
110	2.1	2.5	2.9	3.4	3.8	4.3	4.7	5.2	5.7	6.2
130	2.4	2.9	3.3	3.7	4.2	4.6	5.1	5.6	6.1	6.6
150	2.8	3.2	3.7	4.1	4.6	5.0	5.5	6.0	6.5	7.0
170	3.2	3.6	4.0	4.5	5.0	5.4	5.9	6.4	6.9	7.4
190	3.5	4.0	4.4	4.9	5.4	5.8	6.3	6.8	7.3	7.9
210	3.9	4.3	4.8	5.3	5.8	6.3	6.7	7.3	7.8	8.3
230	4.3	4.7	5.2	5.7	6.2	6.7	7.2	7.7	8.2	8.7
250	4.7	5.2	5.6	6.1	6.7	7.1	7.6	8.2	8.7	9.2

(Continued)

Dominant softwood sites, volume in cords (continued).--

30-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	2.1	2.5	3.0	3.4	3.8	4.3	4.7	5.2	5.7	6.2
30	2.5	2.9	3.3	3.8	4.2	4.7	5.1	5.6	6.1	6.6
50	2.8	3.2	3.7	4.1	4.6	5.1	5.5	6.0	6.5	7.0
70	3.2	3.6	4.1	4.5	5.0	5.5	6.0	6.5	7.0	7.5
90	3.6	4.0	4.5	4.9	5.4	5.9	6.4	6.9	7.4	7.9
110	3.9	4.4	4.9	5.3	5.8	6.3	6.8	7.3	7.8	8.3
130	4.3	4.8	5.3	5.7	6.2	6.7	7.2	7.7	8.3	8.8
150	4.7	5.2	5.7	6.1	6.7	7.1	7.7	8.2	8.7	9.2
170	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.2	9.7
190	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.1	9.6	10.1
210	5.9	6.4	6.9	7.4	7.9	8.5	9.0	9.6	10.1	10.6
230	6.3	6.8	7.3	7.9	8.4	8.9	9.5	10.0	10.6	11.0
250	6.8	7.3	7.8	8.3	8.8	9.4	9.9	10.5	11.0	11.5
40-YEAR-OLD CUTTINGS										
10	3.9	4.4	4.9	5.4	5.9	6.3	6.8	7.3	7.9	8.4
30	4.3	4.8	5.3	5.8	6.3	6.8	7.3	7.8	8.3	8.8
50	4.7	5.2	5.7	6.2	6.7	7.2	7.7	8.2	8.7	9.3
70	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.7	9.2	9.7
90	5.5	6.0	6.5	7.0	7.5	8.1	8.6	9.1	9.7	10.2
110	6.0	6.5	6.9	7.5	8.0	8.5	9.0	9.6	10.1	10.7
130	6.4	6.9	7.4	7.9	8.4	9.0	9.5	10.0	10.6	11.1
150	6.8	7.3	7.8	8.3	8.9	9.4	10.0	10.5	11.0	11.6
170	7.2	7.7	8.3	8.8	9.3	9.9	10.4	11.0	11.5	12.1
190	7.7	8.2	8.7	9.2	9.8	10.3	10.9	11.4	12.0	12.5
210	8.1	8.6	9.1	9.7	10.3	10.8	11.3	11.9	12.5	13.0
230	8.5	9.1	9.6	10.2	10.7	11.3	11.8	12.4	13.0	13.5
250	9.0	9.6	10.1	10.6	11.2	11.7	12.3	12.9	13.4	14.0

(Continued)

Dominant softwood sites, volume in cords (continued).--

50-YEAR-OLD CUTTINGS

Density index	Composition index 10	20	30	40	50	60	70	80	90	100
10	6.0	6.5	7.0	7.5	8.0	8.5	9.1	9.6	10.2	10.7
30	6.4	6.9	7.4	7.9	8.4	9.0	9.5	10.1	10.6	11.2
50	6.8	7.3	7.8	8.4	8.9	9.4	10.0	10.5	11.1	11.7
70	7.2	7.8	8.3	8.8	9.4	9.9	10.5	11.0	11.6	12.1
90	7.7	8.2	8.7	9.3	9.8	10.4	10.9	11.5	12.0	12.6
110	8.1	8.7	9.2	9.7	10.3	10.8	11.4	11.9	12.5	13.1
130	8.6	9.1	9.7	10.2	10.7	11.3	11.9	12.4	13.0	13.6
150	9.0	9.6	10.1	10.7	11.2	11.7	12.3	12.9	13.5	14.1
170	9.5	10.0	10.6	11.1	11.7	12.2	12.8	13.4	14.0	14.6
190	9.9	10.5	11.0	11.6	12.1	12.7	13.3	13.9	14.5	15.1
210	10.4	10.9	11.5	12.1	12.6	13.2	13.8	14.4	15.0	15.6
230	10.9	11.4	12.0	12.5	13.1	13.7	14.3	14.9	15.5	16.1
250	11.3	11.9	12.5	13.1	13.6	14.2	14.8	15.4	16.0	16.6
60-YEAR-OLD CUTTINGS										
10	8.2	8.7	9.2	9.8	10.3	10.8	11.4	12.0	12.5	13.1
30	8.6	9.1	9.7	10.2	10.8	11.3	11.9	12.5	13.0	13.6
50	9.1	9.6	10.1	10.7	11.2	11.8	12.4	12.9	13.5	14.1
70	9.5	10.1	10.6	11.1	11.7	12.3	12.9	13.4	14.0	14.6
90	10.0	10.5	11.1	11.6	12.2	12.8	13.3	13.9	14.5	15.1
110	10.4	11.0	11.5	12.1	12.7	13.3	13.8	14.4	15.0	15.6
130	10.9	11.4	12.0	12.6	13.2	13.7	14.3	14.9	15.5	16.1
150	11.4	11.9	12.5	13.1	13.7	14.3	14.8	15.4	16.0	16.6
170	11.8	12.4	13.0	13.6	14.2	14.7	15.3	15.9	16.5	17.1
190	12.3	12.9	13.5	14.1	14.7	15.3	15.8	16.4	17.0	17.6
210	12.8	13.4	14.0	14.6	15.2	15.7	16.3	16.9	17.5	18.1
230	13.3	13.9	14.5	15.1	15.7	16.3	16.8	17.4	18.0	18.6
250	13.8	14.4	15.0	15.6	16.2	16.7	17.4	17.9	18.5	19.1

I I I

Secondary softwood sites: Total merchantable volume per acre of all trees in 6-inch diameter class and larger

(In cubic feet)

10-YEAR-OLD CUTTINGS

Density index	Composition index 10	20	30	40	50	60	70	80	90
10	6	19	30	41	44	46	47	47	48
20	10	24	37	49	52	54	55	55	56
30	14	29	45	57	61	63	63	64	65
40	19	36	52	66	71	73	73	74	75
50	24	42	61	76	81	83	84	84	85
60	30	50	70	87	93	95	96	97	98
70	36	59	81	99	106	109	110	111	111
80	42	68	92	113	122	124	126	127	128
90	51	78	106	131	142	145	147	149	149
100	59	90	122	153	170	174	177	179	181
110	68	102	141	185	206	211	216	219	222
120	79	118	169	232	271	281	294	297	300
130	90	136	206	309	351	363	372	376	381
140	104	161	269	389	428	435	444	449	451
150	119	195	350	458	486	493	500	502	504
				20-YEAR-OLD CUTTINGS					
10	23	41	59	73	79	80	81	82	82
20	28	49	68	84	90	92	93	94	94
30	34	57	78	96	102	105	106	107	108
40	41	66	90	109	118	120	122	123	124
50	49	76	102	127	136	139	142	144	145
60	57	87	118	148	162	166	170	171	173
70	66	99	136	177	195	200	205	208	211
80	76	113	162	215	248	259	269	274	277
90	88	130	195	288	331	341	351	356	359
100	100	153	246	370	411	420	426	430	433
110	114	186	331	442	474	479	485	488	490
120	131	230	410	497	520	526	532	534	537
130	154	305	472	542	564	569	573	575	577
140	185	389	519	581	600	606	610	612	614
150	232	458	563	618	634	639	642	644	646

(Continued)

Secondary softwood sites, cubic-foot volume (continued).--

30-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	47	73	98	122	131	134	136	137	139
20	55	84	113	142	155	159	162	164	166
30	63	96	131	169	186	192	196	198	201
40	73	110	154	206	232	241	248	252	256
50	84	126	185	269	309	321	330	334	338
60	96	146	230	350	389	402	411	415	419
70	110	176	305	424	458	466	472	475	477
80	127	215	388	484	511	515	520	523	525
90	146	286	456	530	553	558	563	565	567
100	176	367	509	572	591	596	600	602	604
110	215	459	552	608	626	631	634	637	638
120	286	496	590	642	659	663	666	668	671
130	376	542	626	673	688	691	695	697	698
140	449	582	659	701	717	720	723	725	726
150	500	618	688	729	744	746	749	751	752
40-YEAR-OLD CUTTINGS									
10	81	122	176	246	290	301	309	314	318
20	94	142	217	331	374	384	391	397	401
30	107	169	290	411	444	453	460	465	467
40	122	206	374	474	500	507	512	514	515
50	142	271	444	523	544	551	555	557	559
60	171	354	500	565	582	588	592	595	597
70	207	429	544	601	620	624	627	629	631
80	273	485	582	635	651	656	659	661	663
90	357	533	620	667	683	686	689	691	691
100	431	575	651	696	711	715	717	719	720
110	488	612	683	724	738	741	744	745	746
120	535	645	710	750	764	767	769	770	771
130	577	675	737	774	786	788	790	792	793
140	614	703	764	797	808	811	813	815	816
150	647	731	787	819	830	832	834	835	836

(Continued)

Secondary softwood sites, cubic-foot volume (continued).--

50-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	143	248	435	517	537	545	548	550	551
20	167	337	490	556	574	582	584	587	590
30	203	416	537	594	613	619	622	623	626
40	285	480	574	631	645	650	653	656	657
50	371	532	619	662	678	683	688	689	691
60	430	568	645	690	706	710	713	716	718
70	490	604	677	722	735	738	740	742	742
80	537	638	707	747	762	765	768	769	769
90	570	670	732	768	782	784	787	788	789
100	615	702	763	792	805	808	810	811	813
110	643	730	784	815	825	829	830	831	833
120	674	756	805	834	847	850	852	853	856
130	707	778	825	857	867	871	874	876	877
140	732	803	851	880	890	894	896	897	898
150	763	824	872	899	909	910	913	914	916

I V

Secondary softwood sites: Total merchantable volume per acre of all trees in 6-inch diameter class and larger

(In cords)

10-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	0.1	0.2	0.3	0.4	0.5	0.5	0.5	0.5	0.5
20	.1	.3	.4	.5	.6	.6	.6	.6	.6
30	.1	.3	.5	.6	.6	.7	.7	.7	.7
40	.2	.4	.5	.7	.8	.8	.8	.8	.8
50	.3	.4	.6	.8	.9	.9	.9	.9	.9
60	.3	.5	.7	.9	1.0	1.0	1.0	1.0	1.0
70	.4	.6	.9	1.0	1.1	1.1	1.2	1.2	1.2
80	.4	.7	1.0	1.2	1.3	1.3	1.3	1.3	1.3
90	.5	.8	1.1	1.4	1.5	1.5	1.5	1.6	1.6
100	.6	.9	1.3	1.6	1.8	1.8	1.9	1.9	1.9
110	.7	1.1	1.5	1.9	2.2	2.2	2.3	2.3	2.3
120	.8	1.2	1.8	2.4	2.9	3.0	3.1	3.1	3.2
130	.9	1.4	2.2	3.3	3.7	3.8	3.9	4.0	4.0
140	1.1	1.7	2.8	4.1	4.5	4.6	4.7	4.7	4.7
150	1.3	2.1	3.7	4.8	5.1	5.2	5.3	5.3	5.3
20-YEAR-OLD CUTTINGS									
10	0.2	0.4	0.6	0.8	0.8	0.8	0.9	0.9	0.9
20	.3	.5	.7	.9	.9	1.0	1.0	1.0	1.0
30	.4	.6	.8	1.0	1.1	1.1	1.1	1.1	1.1
40	.4	.7	.9	1.1	1.2	1.3	1.3	1.3	1.3
50	.5	.8	1.1	1.3	1.4	1.5	1.5	1.5	1.5
60	.6	.9	1.2	1.6	1.7	1.7	1.8	1.8	1.8
70	.7	1.0	1.4	1.9	2.1	2.1	2.2	2.2	2.2
80	.8	1.2	1.7	2.3	2.6	2.7	2.8	2.9	2.9
90	.9	1.4	2.1	3.0	3.5	3.6	3.7	3.7	3.8
100	1.1	1.6	2.6	3.9	4.3	4.4	4.5	4.5	4.6
110	1.2	2.0	3.5	4.7	5.0	5.0	5.1	5.1	5.2
120	1.4	2.4	4.3	5.2	5.5	5.5	5.6	5.6	5.7
130	1.6	3.2	5.0	5.7	5.9	6.0	6.0	6.1	6.1
140	1.9	4.1	5.5	6.1	6.3	6.4	6.4	6.4	6.5
150	2.4	4.8	5.9	6.5	6.7	6.7	6.8	6.8	6.8

(Continued)

Secondary softwood sites, volume in cords (continued).—

30-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	0.5	0.8	1.0	1.3	1.4	1.4	1.4	1.4	1.5
20	.6	.9	1.2	1.5	1.6	1.7	1.7	1.7	1.7
30	.7	1.0	1.4	1.8	2.0	2.0	2.1	2.1	2.1
40	.8	1.2	1.6	2.2	2.4	2.5	2.6	2.7	2.7
50	.9	1.3	1.9	2.8	3.3	3.4	3.5	3.5	3.6
60	1.0	1.5	2.4	3.7	4.1	4.2	4.3	4.4	4.4
70	1.2	1.9	3.2	4.5	4.8	4.9	5.0	5.0	5.0
80	1.3	2.3	4.1	5.1	5.4	5.4	5.5	5.5	5.5
90	1.5	3.0	4.8	5.6	5.8	5.9	5.9	5.9	6.0
100	1.9	3.9	5.4	6.0	6.2	6.3	6.3	6.3	6.4
110	2.3	4.8	5.8	6.4	6.6	6.6	6.7	6.7	6.7
120	3.0	5.2	6.2	6.8	6.9	7.0	7.0	7.0	7.1
130	4.0	5.7	6.6	7.1	7.2	7.3	7.3	7.3	7.3
140	4.7	6.1	6.9	7.4	7.5	7.6	7.6	7.6	7.6
150	5.3	6.5	7.2	7.7	7.8	7.9	7.9	7.9	7.9
40-YEAR-OLD CUTTINGS									
10	0.9	1.3	1.9	2.6	3.1	3.2	3.3	3.3	3.3
20	1.0	1.5	2.3	3.5	3.9	4.0	4.1	4.2	4.2
30	1.1	1.8	3.1	4.3	4.7	4.8	4.8	4.9	4.9
40	1.3	2.2	3.9	5.0	5.3	5.3	5.4	5.4	5.4
50	1.5	2.9	4.7	5.5	5.7	5.8	5.8	5.9	5.9
60	1.8	3.7	5.3	5.9	6.1	6.2	6.2	6.3	6.3
70	2.2	4.5	5.7	6.3	6.5	6.6	6.6	6.6	6.6
80	2.9	5.1	6.1	6.7	6.9	6.9	6.9	7.0	7.0
90	3.8	5.6	6.5	7.0	7.2	7.2	7.3	7.3	7.3
100	4.5	6.1	6.9	7.3	7.5	7.5	7.5	7.6	7.6
110	5.1	6.4	7.2	7.6	7.8	7.8	7.8	7.8	7.9
120	5.6	6.8	7.5	7.9	8.0	8.1	8.1	8.1	8.1
130	6.1	7.1	7.8	8.1	8.3	8.3	8.3	8.3	8.3
140	6.5	7.4	8.0	8.4	8.5	8.5	8.6	8.6	8.6
150	6.8	7.7	8.3	8.6	8.7	8.8	8.8	8.8	8.8

(Continued)

Secondary softwood sites, volume in cords (continued).--

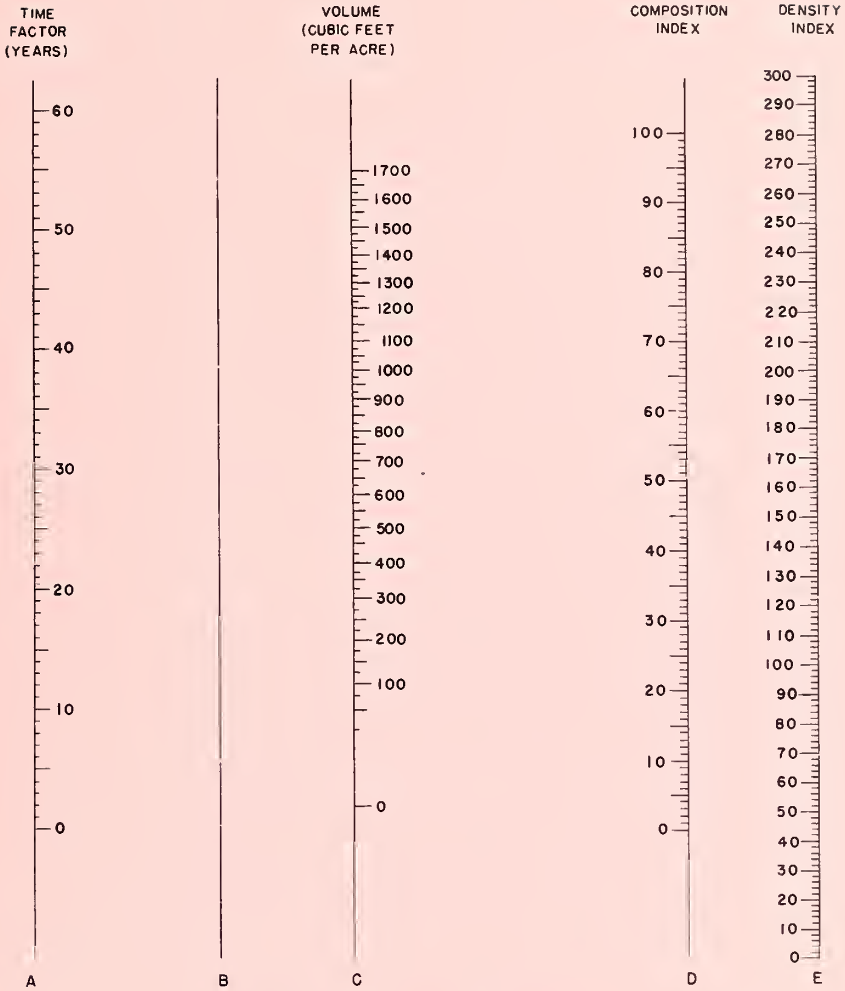
50-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	1.5	2.6	4.6	5.4	5.7	5.7	5.8	5.8	5.8
20	1.8	3.5	5.2	5.9	6.0	6.1	6.1	6.2	6.2
30	2.1	4.4	5.7	6.3	6.5	6.5	6.5	6.6	6.6
40	3.0	5.1	6.0	6.6	6.8	6.8	6.9	6.9	6.9
50	3.9	5.6	6.5	7.0	7.1	7.2	7.2	7.3	7.3
60	4.5	6.0	6.8	7.3	7.4	7.5	7.5	7.5	7.6
70	5.2	6.4	7.1	7.6	7.7	7.8	7.8	7.8	7.8
80	5.7	6.7	7.4	7.9	8.0	8.1	8.1	8.1	8.1
90	6.0	7.1	7.7	8.1	8.2	8.3	8.3	8.3	8.3
100	6.5	7.4	8.0	8.3	8.5	8.5	8.5	8.5	8.6
110	6.8	7.7	8.3	8.6	8.7	8.7	8.7	8.7	8.8
120	7.1	8.0	8.5	8.8	8.9	8.9	9.0	9.0	9.0
130	7.4	8.2	8.7	9.0	9.1	9.2	9.2	9.2	9.2
140	7.7	8.5	9.0	9.3	9.4	9.4	9.4	9.4	9.5
150	8.0	8.7	9.2	9.5	9.6	9.6	9.6	9.6	9.6

ALINEMENT CHART I

FOR DETERMINING MERCHANTABLE SPRUCE-FIR VOLUME

ON DOMINANT SOFTWOOD SITES, IN CUBIC FEET

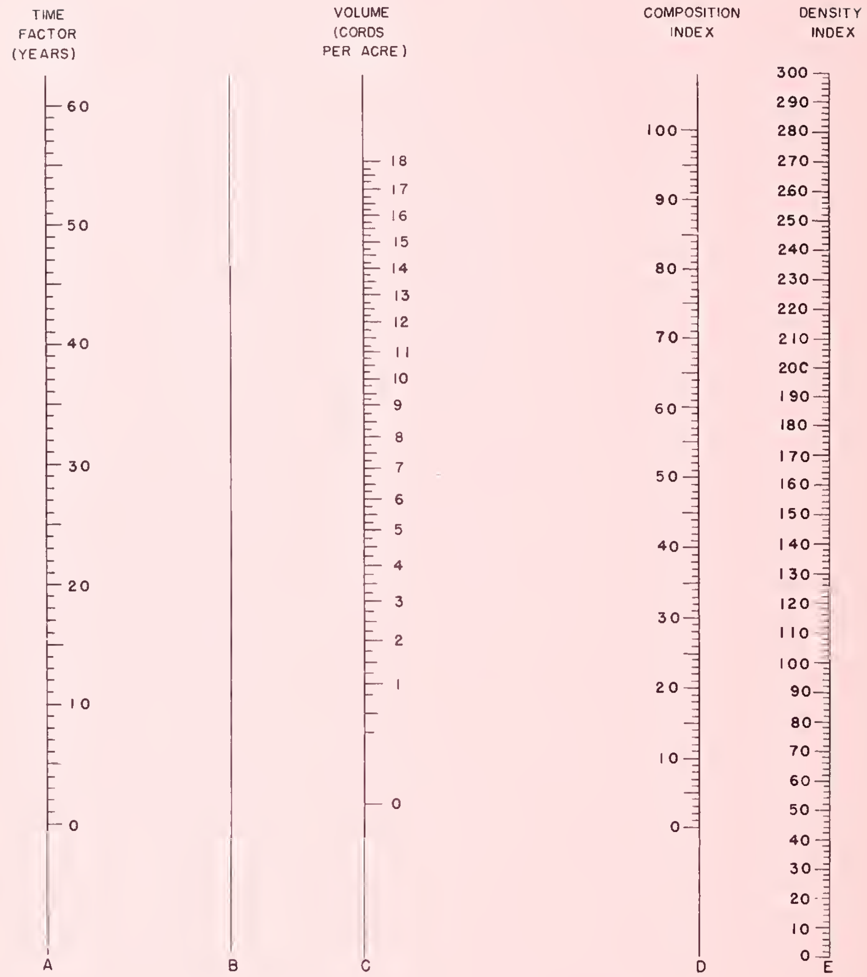


KEY: A TO D, HOLD B; TO E, READ C

ALINEMENT CHART 2

FOR DETERMINING MERCHANTABLE SPRUCE-FIR VOLUME

ON DOMINANT SOFTWOOD SITES, IN CORDS

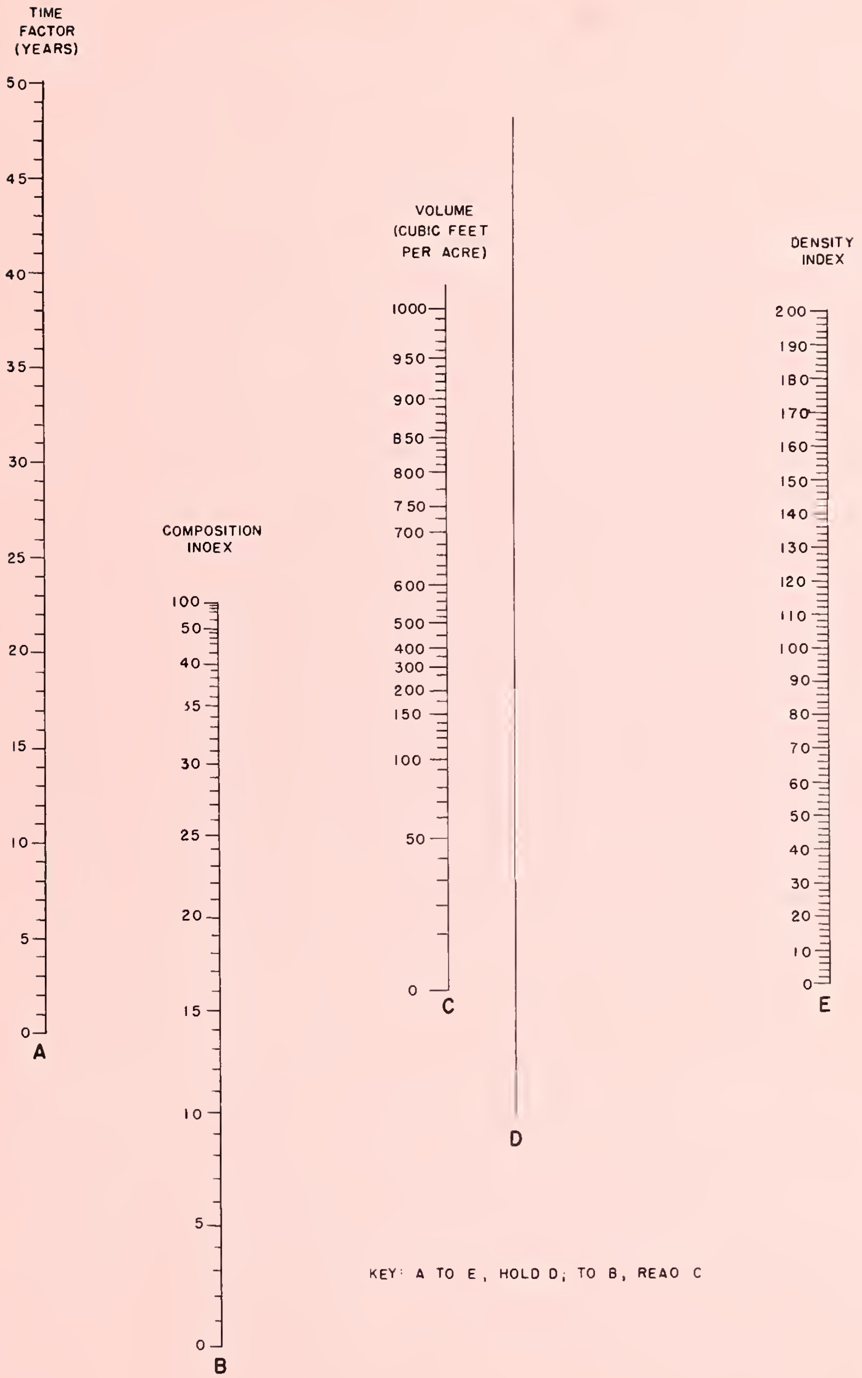


KEY: A TO D, HOLD B; TO E, READ C

ALINEMENT CHART 3

FOR DETERMINING MERCHANTABLE SPRUCE-FIR VOLUME

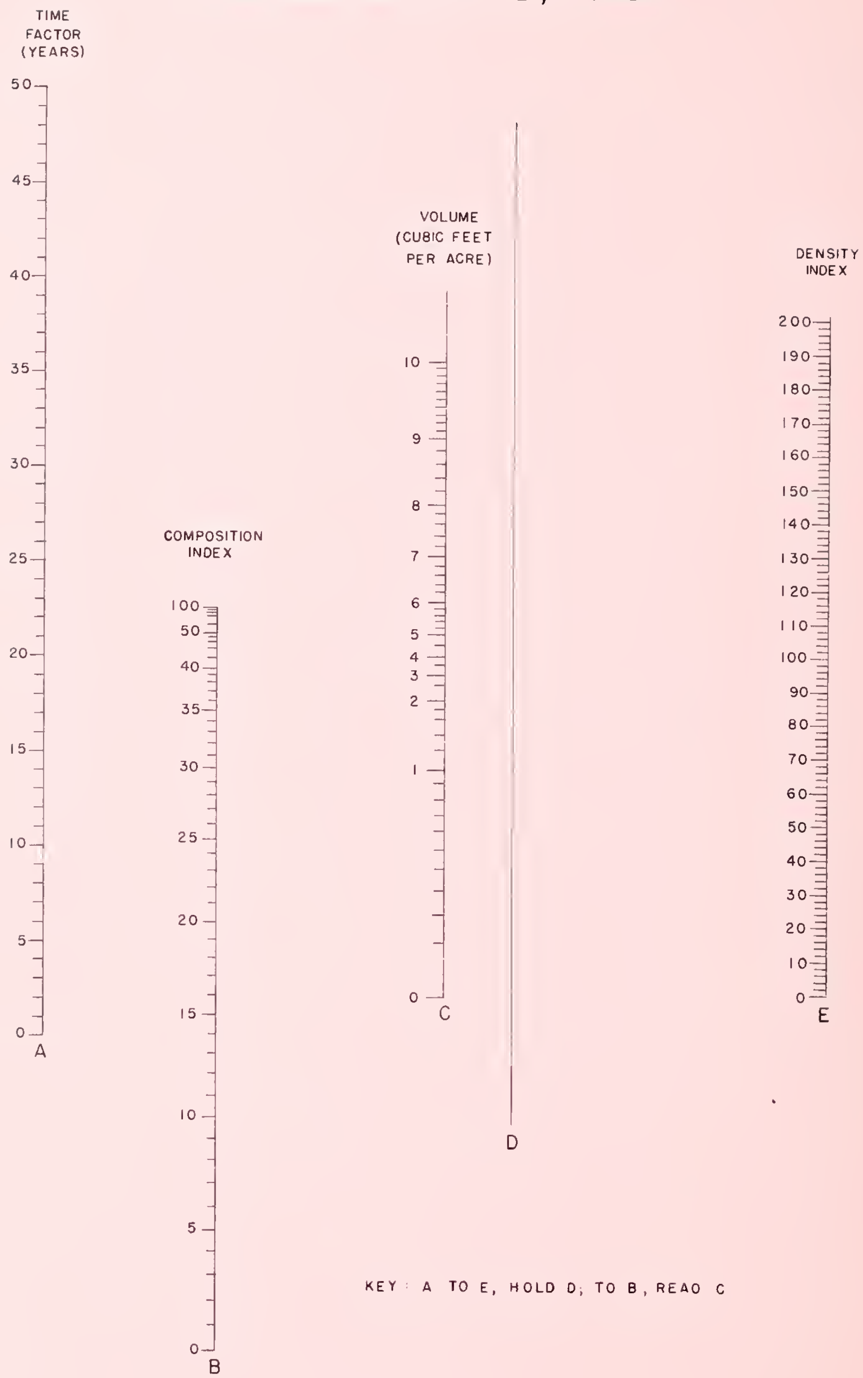
ON SECONDARY SOFTWOOD SITES, IN CUBIC FEET



ALINEMENT CHART 4

FOR DETERMINING MERCHANTABLE SPRUCE-FIR VOLUME

ON SECONDARY SOFTWOOD SITES, IN CORDS



III

APPLYING THE YIELD TABLES

TO A TRACT OF TIMBER

DATA REQUIRED

TO APPLY THE YIELD TABLES to any given tract it is necessary to know for each stand (1) the site-type class, (2) the elapsed time since cutting, (3) the effective age, (4) the composition index, (5) the stand-density index, (6) the expected change in stand density, and (7) the acreage by age classes.

Forest Inventory

Any of the commonly used systems of forest inventory can be used. Where no such inventory of an area exists, a new one will be necessary.

The intensity of the inventory will be determined by the degree of accuracy desired. Bear in mind that the more heterogeneous the stand conditions, the greater the number of plots or strips required to attain a given degree of accuracy. Accuracy within a 10-percent error of estimate for total volume seems to be a reasonable goal.

Supplementary Data

Certain kinds of data not ordinarily called for in a regular inventory cruise are required for effective use of the yield tables. Whatever system of survey is used--strip, line-plot, or a combination of either with aerial photography--trees of unmerchantable size (those down to and including 1 inch d.b.h.) must be recorded along with merchantable-size trees.

This is essential because the amount of sapling growth present is an important factor in final yields. The unmerchantable-size trees, however, need be tallied only on a portion of the plot or cruise strip--for example, on a 1/50-acre subplot within the cruise plot. Such a sample is adequate for the work.

Another important part of the survey is to classify the tract by the broad site-type groups and by age of cut-over area. This is important because these classes delimit the areas for which cruise plots or strips must be grouped and for which data must be compiled preliminary to yield calculations. The boundaries and areas of these classes can be determined by any of the numerous methods ordinarily used in forest-survey work.

To simplify the calculations, cut-over areas may be grouped into age classes. In the example cited later, 5-year intervals between age classes were used; areas cut 3 to 7 years ago being classed as 5-year-old cut-overs, those cut 8 to 12 years ago as 10-year-old cut-overs, and so on. Where areas have been subjected to repeated and sporadic cutting it may be difficult or impossible to determine average age of cut-over. Under such circumstances the area need be classified only into the two major site-type classes, and the effective age of each can be determined.

The required stand data can be computed readily from stand tallies compiled for each plot or cruise strip. By combining all plots that comprise a given age-of-cutting area, the mean of the stand-data values can be calculated for each age of cutting. Once these values are known, relative density, composition index, and other essential factors can be calculated by the methods described below.

AN EXAMPLE

As an illustration, the steps involved in estimating future yields will be applied to a typical tract in the spruce-fir region. The tract selected as an example is the Spruce Pond watershed in northern Maine. Data based on a line-plot survey are available for this tract (table 7).

Table 7.--Inventory data for Spruce Pond watershed

Cover class	Area	Cover class	Area
	Acres		Acres
Commercial forest land:		Noncommercial forest land:	
Dominant softwood:		Bog growth and flowage	90
10-year-old cuttings	750	Hard burns	130
20-year-old cuttings	150		220
30-year-old cuttings	600	Other land:	
40-year-old cuttings	300	Pasture	300
	1,800	Cultivated land	20
Secondary softwoods:		Waste land	30
10-year-old cuttings	500		350
20-year-old cuttings	300	Ponds and water courses	530
30-year-old cuttings	500	Total land area	5,000
40-year-old cuttings	100		
	1,400		
Northern hardwoods	400		
Cedar-tamarack	300		
Total commercial forest	3,900		

Table 8.--Stand data needed for each plot in calculating spruce-fir yields 20 years in future

(For Plot 7 in Spruce Pond watershed)

Item	Data
Site ....class..	Dominant softwoods
Age of cutting ....years..	10
Average stand per acre (1 inch d.b.h. and larger):	
Spruce and fir trees ....number..	696
Hardwoods and others ....number..	400
All trees ....number..	1,096
Basal area ....square feet..	82.94
Average d.b.h. ....inches..	3.7
Measured spruce-fir volume per acre .....cords..	2.0
Composition index ....units..	64
Density index (present) ....units..	121
Effective age (present) ....years..	5
Density index (20 years hence) ....units..	194
Effective elapsed time since cutting ....years..	25

This area is similar to thousands of acres of cut-over land throughout the spruce-fir region that have been operated for pulpwood since the turn of the century.

The 10-year-old cut-over areas in the dominant soft-wood sites of the Spruce Pond watershed are used in this example. Values that need to be determined for each plot are indicated in table 8. This shows the data for Plot 7. The tract contains 8 plots (table 9).

Computing Stand Data

Area, by site and age of cutting — Following completion of the forest survey for the Spruce Pond watershed, field maps were combined into a project map. Next the acreages of the two site-type classes and the various age classes were determined (table 7).

Average number of trees and basal area per acre — Number of trees and basal area[3] per acre (table 9) were transcribed directly from the stand tables already computed. For example, Plot 7 contained 1,096 trees per acre, with a total basal area of 82.94 square feet. In determining average number of trees and basal area for the entire tract, all eight plots in it were used as a basis. Two species groups, (1) spruce and fir and (2) all other species, were totalled.[4]

Average d.b.h. of the stand — First the basal area of the average tree on each plot was determined by dividing the plot's total basal area by its total number of trees. The diameter corresponding to the basal area of the average tree is its average diameter.

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[3]A simple method of computing basal area by formula is described by C. A. Bickford in Jour. Agr. Res. 51: 425-434 1935. His formula is:

$$\text{Basal area in square feet} = \left[\frac{\pi}{4(144)}\right]\left[\begin{matrix}\text{Sum of the}\\ \text{square of d.b.h.}\end{matrix}\right] = \left[0.005454\ldots\right]\left[\Sigma d^2\right]$$

[4]Where only spruce-fir yields are desired, a group consisting of only these species would be recognized. If spruce-fir-hemlock yields were sought, hemlock would be added to the spruce-fir group and carried through all the calculations for spruce-fir. This would leave the second group to be dealt with, consisting of all the remaining species--hardwoods, cedar, pine, etc.

For example, the total basal area per acre for Plot 7 was 82.94 square feet. Dividing this by 1,096 (total number of trees per acre) gave a basal area of 0.0757 square feet for the average tree. The table for areas of circles (table 16, in Appendix) shows the diameter of a circle of that area to be 3.7 inches. Next the average d.b.h.'s for the individual plots were totalled. This total, 30.4, divided by 8 (the number of plots in the unit) = 3.80 inches, the average d.b.h. of the stand.

Merchantable spruce-fir volume per acre

To obtain a measure of merchantable spruce-fir volume per acre, the number of spruce and fir stems in each diameter class (6 inches d.b.h. and above) were first determined. Volumes were then computed for each diameter class through the use of appropriate volume tables. For the example cited in table 9, the volume table shown in the Appendix (table 18) was used. Adding up the volumes in the various diameter classes gave the total volume for Plot 7 of 2.0 cords per acre (table 8). The volume of 3.1 cords per acre shown for the cutting area (table 10) is the mean of the eight plots in the area.

Computing Growth Factors

Composition index

The composition index of 64 for Plot 7 was arrived at by dividing 696 (number of spruce and balsam fir trees) by 1,096 (total number of of all trees). Thus 696 ÷ 1,096 = 0.64; 0.64 x 100 = 64.

Table 9.--Sample work sheet for compiling data needed to determine stand-table values per acre

(Spruce Pond watershed--10-year-old cuttings on dominant softwood sites)

Plot No.	Spruce and fir	Hardwoods and others	All trees	Total basal area	D.b.h. of average tree	Measured merchantable volume per acre	
	Number	Number	Number	Sq.ft.	Inches	Cu.ft.	Cords
7	696	400	1096	82.94	3.7	194	2.0
8	928	208	1136	82.36	3.6	226	2.4
23	168	72	240	49.42	6.2	511	5.4
24	176	72	248	30.13	4.7	330	3.5
25	296	40	336	20.84	3.4	234	2.5
59	592	112	704	24.60	2.5	201	2.1
60	456	24	480	19.24	2.7	252	2.6
83	480	608	1088	77.55	3.6	438	4.6

Density index (present) Since the density index of a cutting unit equals the mean density of the plots that comprise the unit, density values must be calculated for individual plots. For example, the current density index of 121 for Plot 7 was arrived at by dividing 1,096 (total number of all trees) by 910 (total number of trees indicated in the density reference table--table 13, in Appendix--for an average stand diameter of 3.7 inches. Adding up the density values of the eight plots in the unit and dividing the total (576) by 8 gave the present stand-density index of 72 for the unit (table 10).

Effective age (present) Although effective age can be determined from the yield tables by interpolation, the alinement charts (pp. 38 - 41) provide a quicker means of figuring effective age. Effective age can be read directly from these charts by carrying out in reverse the procedures for computing yield. The method can be illustrated by listing the steps followed in arriving at the present effective age of 13 for the 10-year-old cutover area in the dominant softwood site (table 10):

1. Use alinement chart 2. Lay a straightedge across the graduated volume scale at 3.1 cords (the measured merchantable volume) and the density scale at 72 (the density index).

Table 10.--Work-sheet summary of stand data, showing corrections for density changes and cutting ages

(Spruce Pond watershed--10-year-old cuttings on dominant softwood sites)

Plot No.	Present					20 years hence				
	Composition index	Density index	Measured volume per acre		Effective age	Effective age	Composition index	Density index	Predicted volume per acre	
	Units	Units	Cu.ft.	Cords	Years	Years	Units	Units	Cu.ft.	Cords
7	64	121	194	2.0	5	--	--	--	--	--
8	82	123	226	2.4	3	--	--	--	--	--
23	70	46	511	5.4	29	--	--	--	--	--
24	71	34	330	3.5	15	--	--	--	--	--
25	88	34	234	2.5	11	--	--	--	--	--
59	84	59	201	2.1	7	--	--	--	--	--
60	95	42	252	2.6	9	--	--	--	--	--
83	44	117	438	4.6	25	--	--	--	--	--
Total	598	576	2386	25.1	104	--	--	--	--	--
Mean	75	72	298	3.1	13	33	75	140	790	8.3

2. Mark the point where the straightedge intersects the ungraduated scale.

3. Hold on this point and shift the straightedge to 75 (the composition index) on the composition scale.

4. Then read the point at which the straightedge intersects the time scale for the effective age of the stand. In this case it is 13.

The present effective age for the cutting unit is the mean of the eight plots in the unit.

Density index (20 years hence) — The future density of a stand can be determined by consulting table 14 (in the Appendix), which shows the change in density index over a 10-year period for dominant softwood stands of different densities and ages of cut-over areas. (For secondary softwood sites use table 15.) Future density is calculated by successive 10-year steps, the density at the end of the first period being taken as the starting point for the second period, and so on.

For example, the cutting unit under discussion has an effective age of 13 and a present density index of 72. Ten years from now its density will be 119 (72 plus 46), a density increase of 46 over the 10-year period. After another 10 years the density index will have increased to 140 (119 plus 22).

Effective elapsed time since cutting — Effective elapsed time since cutting is determined by adding to the effective age the number of years hence for which the yield prediction is desired. The effective elapsed time for the unit under discussion is the unit's effective age (13) plus 20 (the number of years hence). Thus the effective elapsed time is 33 years.

Computing Yield

After effective age, density index, and composition index have been computed for the various ages of cuttings that make up the two broad site-type groups, predictions of yield can be made. Where quick and precise values are desired, yields should be read from alinement charts 1 and 2. For the area in this example, the following are the steps:

1. Lay a straightedge across the time scale at 33 and the composition scale at 75.

2. Mark the point where the straightedge intersects the ungraduated scale.

3. Hold on this point and shift the straightedge to 140 on the density scale.

4. Then read the point at which the straightedge intersects the volume scale. In this case it is 8.3 cords or 790 cubic feet per acre.

When alinement charts are not available, reasonably accurate estimates can be obtained by interpolating in the yield tables.

To obtain the total expected yield for the cutting unit, simply multiply its acreage (750) by these per-acre volume figures. This volume totals 592,500 cubic feet or 6,225 cords (table 11). This is the predicted volume for the 10-year-old cut-over areas in the dominant softwood sites.

Table 11.--Stand data and spruce-fir yield predictions 20 years hence for Spruce Pond watershed

DOMINANT SOFTWOOD SITES

Present			20 years hence						
Age of cutting	Effective age	Area	Effective age	Composition index	Density index	Predicted volumes: Per acre		Predicted volumes: Total area	
Years	Years	Acres	Units	Units	Units	Cu.ft.	Cords	Cu.ft.	Cords
10	13	750	33	75	135	790	8.3	592,500	6,225
20	18	150	38	67	141	870	9.2	130,500	1,380
30	33	600	53	80	128	1,250	13.2	750,000	7,920
40	38	300	58	83	117	1,350	14.2	405,000	4,260
Total	--	1,800	--	--	--	--	--	1,869,000	19,785
SECONDARY SOFTWOOD SITES									
10	8	500	28	58	101	580	6.1	290,000	3,050
20	22	300	42	40	126	790	8.3	237,000	2,490
30	28	500	48	19	105	680	7.2	340,000	3,600
40	42	100	62	24	115	860	9.0	86,000	900
Total	--	1,400	--	--	--	--	--	953,000	10,040
All cuttings	--	3,200	--	--	--	--	--	2,822,000	29,825

To determine the total predicted yield for the Spruce Pond watershed, these calculations should be repeated for all age-class units in the two site-type groups (table 11).

ACCURACY OF THE YIELD TABLES

The question quite naturally arises as to how adequate these yield tables are for forest-management purposes. For any particular holding this depends on how intensively the lands are being managed. Over the spruce-fir region at large a pioneer stage of management still prevails. Extensive holdings are being managed under the one-harvest-cut-per-rotation system. It is believed that under this type of management the yield tables will prove adequate for predicting growth and yield--especially for areas of more than 1,000 acres.

In attempting to evaluate the accuracy of the yield tables, two questions need to be answered: (1) How closely do the yield-table values approach the actual yields of the re-measured plots? and (2) How accurate are the cruise data for the tract?

Analysis of the re-measurement data over a 15-year period on 93 of the original 365 plots used in developing the yield tables helps to answer the first question. A summary of the analyses for both the dominant and secondary softwood sites appears in table 12. Note that deviation of the estimated volume from the mean actual volume averaged 109.9 cubic feet for the dominant softwood sites and 70.1 cubic feet for the secondary softwood sites.

The standard deviations of the differences of 15-year future volume in cubic feet for individual plots range from a low of 7.1 percent to a high of 31.4 percent of the yield for the dominant softwood sites. For secondary softwood sites the range is from 34.9 percent to 40.4 percent.

Although actual yields of individual 1/8-acre units differ rather widely from tabular values, the error of the mean diminishes rapidly as the number of units comprising the sample is increased. For the 59 growth plots that comprise the softwood sites, the standard error of the mean deviation from actual yield amounts to less than 4 percent.

Use of about 170 plots would reduce the error to less than 2 percent.

Table 12.—Check of actual and estimated yield per acre over a 15-year period with corrections applied for density changes and effective cutting ages

DOMINANT SOFTWOOD SITES

Age of cutting	Actual mean volume	Estimated volume: Mean deviation from actual	Estimated volume: Standard deviation		Basis: number of plots
	Cu.ft.	Cu.ft.	Cu.ft.	Percent	
14	403.5	155.2	119.15	29.5	4
32	1,505.0	-258.4	472.82	31.4	12
35	991.4	49.6	246.01	24.08	14
42	2,576.6	-513.4	420.59	16.3	11
47	1,793.2	77.1	466.66	26.0	14
59	2,607.0	- 33.2	195.28	7.5	4
Mean	1,651.3	-109.9	439.63	26.6	--
SECONDARY SOFTWOOD SITES					
28	707.3	- 20.1	260.48	36.8	16
29	529.5	68.0	184.77	34.9	4
46	1,431.8	-166.8	578.24	40.4	14
Mean	985.3	- 70.1	416.11	42.2	--

The second question, accuracy of the inventory cruise, is important because the growth factors used in predicting yields are derived from the basic cruise data. Thus the accuracy of the yield predictions from the tables will depend on--and cannot exceed--the accuracy of the cruise data.

Accuracy of the inventory cruise can be determined from the cruise itself. Once the variability of the stand and the number of plots are determined it is a simple matter to compute the expected limits of the accuracy of the cruise. The error in sampling inventory is bound to exceed that encountered in growth prediction. This is to be expected, because the ratio of growth to growing stock is relatively small.

However, inventory cruises today are commonly undertaken with sufficient intensity to assure volume accuracies

of within 10 percent. Such accuracy normally entails the establishment of several hundred plots. This is considerably greater than the minimum of 170 plots required for a growth error of less than 2 percent. Thus an over-all accuracy for the yield tables of ± 12 percent is a reasonable expectation. Such a degree of accuracy should suffice for most situations.

Where valuable stands are at stake or where the need for heavy outlays for roads and other logging improvements are indicated, the cost of attaining greater accuracy may be justified. To attain an accuracy of ± 6 percent would require the use of four times as many plots as for the ± 12 percent accuracy cited above.

The yield tables have their limitations. They show only the volume of surviving trees; therefore they fail to show the volume that is lost through mortality. Through a shift from the one-harvest-cut-per-rotation to shorter-cycle cuttings a high proportion of this mortality could be salvaged. As expanded road systems make higher levels of forestry practice feasible, partial-cutting systems will largely supplant the long-cutting-cycle system now in vogue.

The frequent cuttings that characterize selection cutting ultimately create uneven-aged stands. It does not follow, however, that the yield tables cannot be applied with reasonable success to selectively cut stands. Residual growing stock, expressed as effective age, definitely enters into the calculation of future yield. Since greater yields are expected under selection cuttings, yield-table values will probably be on the conservative side.

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I V

APPENDIX

Table 13.--Average number of trees per acre, for use in determining stand density[1] in the spruce-fir region of the Northeast

(Basis: reference curve based on 365 plots)

Tree diameter breast high, in inches and additional 10ths of inches										
Inches	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	1,660	1,625	1,590	1,560	1,530	1,500	1,465	1,435	1,405	1,375
2	1,345	1,315	1,285	1,260	1,230	1,200	1,175	1,150	1,125	1,100
3	1,075	1,050	1,025	1,000	975	950	930	910	890	870
4	850	830	815	800	782	765	748	732	716	700
5	685	670	655	640	625	610	595	582	569	555
6	543	530	518	506	495	485	474	462	452	442
7	433	424	415	406	398	391	384	376	367	360
8	352	344	337	330	323	316	309	302	296	290
9	283	276	269	263	257	251	246	240	235	230
10	225	220	215	210	205	200	195	191	187	183

[1]To determine the density of any given spruce-fir stand, divide its total number of trees per acre by the total number of trees indicated in the above table for the same average diameter stand.

Table 14.--Change in density index during a 10-year period for spruce-fir stands of different densities and ages of cutting[1]

(In density-index units)

DOMINANT SOFTWOOD SITES

Density index at beginning of period	Age of cutting[2] at beginning of period, in years																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	56	48	41	34	28	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
30	62	53	46	40	34	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
40	65	57	49	41	33	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
50	68	59	51	42	33	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
60	70	60	52	42	32	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
70	72	61	53	42	32	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
80	70	60	52	41	31	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
90	68	59	51	40	30	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
100	65	57	49	40	30	21	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
110	63	55	47	37	28	20	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
120	62	53	45	36	26	20	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
130	60	50	42	33	24	19	13	10	7	5	4	3	2	2	1	1	0	0	- 1	- 1	- 2
140	57	46	38	30	22	17	12	10	7	5	3	2	1	1	0	0	- 1	- 1	- 2	- 2	- 4
150	54	42	34	27	20	16	11	9	6	5	3	2	1	1	0	0	- 1	- 1	- 2	- 2	- 3
160	51	38	30	24	17	13	9	7	5	3	1	0	- 1	- 1	- 2	- 2	- 3	- 3	- 4	- 4	- 5
170	--	34	26	21	15	11	7	5	3	1	- 1	- 2	- 3	- 4	- 4	- 4	- 5	- 5	- 6	- 6	- 7
180	--	--	22	18	13	9	5	3	0	-1	- 3	- 4	- 5	- 5	- 6	- 6	- 7	- 7	- 8	- 8	- 9
190	--	--	--	--	10	6	2	0	-3	-4	- 6	- 7	- 8	- 8	- 9	- 9	-10	-10	-11	-11	-12
200	--	--	--	--	--	--	0	-3	-6	-8	-10	-11	-12	-13	-14	-14	-15	-15	-15	-15	-16

[1]For density index at end of 10-year period add amount of change to density at beginning of period.

[2]Either actual or effective age; a stand's effective age is defined in terms of the age of cutting it most nearly resembles with respect to density.

Table 15.--Change in density index during a 10-year period for spruce-fir stands of different densities and ages of cutting[1]

(In density-index units)

SECONDARY SOFTWOOD SITES

Density index at beginning of period	Age of cutting[2] at beginning of period, in years																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	28	25	23	21	20	20	20	20	20	20	20	19	19	19	19	19	19	18	18	18	18
30	28	25	23	21	19	19	18	18	18	18	18	17	17	17	17	17	17	16	16	16	16
40	28	25	23	20	18	17	16	16	16	16	16	16	16	15	15	15	15	15	14	14	14
50	27	24	22	19	16	15	14	14	14	14	14	14	13	13	13	13	13	12	12	12	12
60	27	24	22	18	14	13	12	12	12	12	12	12	11	11	11	11	11	10	10	10	10
70	27	24	22	17	12	11	10	10	9	9	9	9	8	8	8	8	8	7	7	7	7
80	27	24	22	16	10	9	8	8	8	8	8	8	7	7	7	7	7	6	6	6	6
90	27	24	22	15	9	7	6	6	5	5	5	5	4	4	4	4	4	3	3	3	3
100	27	24	22	14	7	6	4	4	3	3	3	3	2	2	2	2	2	1	1	1	1
110	25	23	21	13	6	4	2	1	0	0	0	0	- 1	- 1	- 1	- 1	- 1	- 2	- 2	- 2	- 2
120	25	23	21	12	4	2	0	- 1	- 2	- 2	- 2	- 2	- 3	- 3	- 3	- 3	- 3	- 4	- 4	- 4	- 4
130	24	22	20	11	2	0	- 2	- 3	- 4	- 4	- 4	- 4	- 5	- 5	- 5	- 5	- 5	- 6	- 6	- 6	- 6
140	24	22	20	10	0	- 2	- 5	- 5	- 6	- 6	- 6	- 6	- 7	- 7	- 7	- 7	- 7	- 8	- 8	- 8	- 8
150	23	21	19	9	-2	- 5	- 7	- 8	- 9	- 9	- 9	- 9	-10	-10	-10	-10	-10	-11	-11	-11	-11
160	23	21	19	8	-4	- 8	-10	-11	-12	-12	-12	-12	-13	-13	-13	-13	-13	-14	-14	-14	-14
170	22	20	18	7	-6	-11	-13	-14	-15	-15	-15	-15	-16	-16	-16	-16	-16	-17	-17	-17	-17
180	21	19	17	6	-7	-11	-16	-17	-18	-18	-18	-18	-19	-19	-19	-19	-19	-20	-20	-20	-20

[1]For density index at end of 10-year period add amount of change to density at beginning of period.

[2]Either actual or effective age; a stand's effective age is defined in terms of the age of cutting it most nearly resembles with respect to density.

Table 16.--Basal areas, in square feet, for trees of various diameters

Tree diameter breast high, in inches and additional 10ths of inches										
Inches	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	--	0.0001	0.0002	0.0005	0.0009	0.0014	0.0020	0.0027	0.0035	0.0044
1	0.0055	.0067	.0079	.0092	.0107	.0123	.0140	.0158	.0177	.0197
2	.0218	.0240	.0264	.0289	.0314	.0341	.0369	.0398	.0428	.0459
3	.0491	.0524	.0559	.0594	.0631	.0669	.0707	.0747	.0788	.0830
4	.0873	.0917	.0963	.1009	.1056	.1105	.1154	.1205	.1257	.1310
5	.1364	.1418	.1474	.1532	.1590	.1650	.1710	.1772	.1835	.1899
6	.1963	.2029	.2096	.2164	.2234	.2304	.2376	.2448	.2522	.2597
7	.2673	.2750	.2828	.2907	.2987	.3068	.3151	.3234	.3319	.3404
8	.3491	.3579	.3668	.3758	.3849	.3941	.4034	.4129	.4224	.4321
9	.4418	.4517	.4617	.4718	.4820	.4923	.5027	.5132	.5238	.5345
10	.5454	.5564	.5675	.5787	.5900	.6014	.6129	.6245	.6362	.6481
11	.6600	.6721	.6842	.6965	.7089	.7214	.7340	.7467	.7595	.7724
12	.7854	.7986	.8118	.8252	.8387	.8523	.8660	.8798	.8937	.9077
13	.9218	.9360	.9504	.9648	.9794	.9941	1.0089	1.0237	1.0387	1.0538
14	1.0690	1.0843	1.0997	1.1153	1.1309	1.1467	1.1626	1.1785	1.1946	1.2108
15	1.2272	1.2437	1.2602	1.2768	1.2936	1.3104	1.3274	1.3444	1.3616	1.3789
16	1.3963	1.4138	1.4314	1.4492	1.4670	1.4849	1.5030	1.5212	1.5394	1.5578
17	1.5763	1.5949	1.6136	1.6324	1.6513	1.6703	1.6894	1.7087	1.7280	1.7475
18	1.7671	1.7868	1.8066	1.8265	1.8465	1.8666	1.8869	1.9072	1.9277	1.9482
19	1.9689	1.9897	2.0106	2.0316	2.0527	2.0739	2.0952	2.1167	2.1382	2.1599
20	2.1817	2.2036	2.2256	2.2477	2.2699	2.2922	2.3146	2.3371	2.3597	2.3825
21	2.4053	2.4283	2.4514	2.4745	2.4978	2.5212	2.5447	2.5684	2.5921	2.6159
22	2.6398	2.6638	2.6880	2.7122	2.7366	2.7611	2.7857	2.8104	2.8352	2.8602
23	2.8852	2.9103	2.9356	2.9610	2.9864	3.0120	3.0377	3.0635	3.0894	3.1154
24	3.1416	3.1679	3.1942	3.2207	3.2471	3.2748	3.3006	3.3275	3.3545	3.3816
25	3.4088	3.4361	3.4636	3.4911	3.5188	3.5465	3.5744	3.6024	3.6305	3.6587

Table 17.--Spruce-fir volume table[1]: Total cubic-foot volume inside bark (peeled wood) and exclusive of butt swell

(Form Class 67)

	Tree diameter breast high, in inches and additional 10ths of inches									
Inches	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.05	0.06	0.07	0.08	0.09	0.11	0.13	0.15	0.17	0.19
2	.22	.26	.30	.34	.38	.42	.46	.50	.55	.60
3	.65	.70	.75	.80	.86	.92	.99	1.06	1.13	1.20
4	1.27	1.34	1.41	1.48	1.55	1.63	1.72	1.81	1.90	2.00
5	2.10	2.20	2.30	2.40	2.50	2.61	2.73	2.85	2.97	3.10
6	3.7	3.9	4.1	4.3	4.4	4.6	4.8	4.9	5.1	5.3
7	5.3	5.5	5.8	6.0	6.2	6.4	6.6	6.8	7.1	7.3
8	7.3	7.7	8.0	8.2	8.4	8.6	8.8	9.0	9.4	9.7
9	10.0	10.2	10.5	10.7	11.1	11.4	11.6	11.9	12.2	12.6
10	12.7	13.2	13.5	13.8	14.1	14.4	14.8	15.3	15.7	16.1
11	16.4	16.8	17.1	17.4	17.7	18.0	18.4	18.8	19.2	19.6
12	20.0	20.4	20.8	21.3	21.7	22.1	22.5	22.9	23.4	24.0
13	24.4	24.8	25.2	25.6	26.0	26.5	26.9	27.3	27.7	28.1
14	28.5	29.1	29.7	30.2	30.8	31.4	32.0	32.6	33.2	33.9
15	34.5	35.0	35.6	36.1	36.8	37.3	37.9	38.4	39.1	39.6
16	40.2	40.9	41.6	42.3	42.9	43.6	44.4	45.1	45.7	46.5
17	46.9	47.6	48.3	49.1	49.8	50.5	51.3	52.0	52.7	53.4
18	54.3	55.0	55.8	56.6	58.2	58.1	59.0	59.7	60.5	61.3
19	61.9	62.5	63.2	63.9	64.6	65.2	65.9	66.7	67.3	68.0
20	68.8	69.4	70.1	70.7	71.5	72.1	72.8	73.4	74.2	74.9
21	75.8	76.7	77.6	78.4	79.4	80.2	81.1	82.0	82.9	83.9
22	85.0	85.9	86.9	87.8	88.8	89.7	90.6	91.6	92.5	93.4

[1]Based on Behre's form-class volume tables (1).

Table 18.--Spruce-fir volume table[1]: Merchantable cubic-foot volume to 3-inch top inside bark (peeled wood) and with 1-foot stump allowance

(Form Class 67)

	Tree diameter breast high, in inches and additional 10ths of inches									
Inches	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
4	0.86	0.91	0.96	1.00	1.05	1.11	1.17	1.23	1.29	1.36
5	1.74	1.83	1.91	2.00	2.08	2.17	2.26	2.36	2.46	2.57
6	3.25	3.40	3.60	3.75	3.90	4.05	4.20	4.35	4.50	4.70
7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7
8	6.9	7.2	7.5	7.7	7.9	8.1	8.3	8.5	8.8	9.1
9	9.4	9.6	9.9	10.1	10.4	10.7	10.9	11.2	11.5	11.8
10	12.1	12.5	12.8	13.1	13.4	13.7	14.1	14.5	14.9	15.3
11	15.7	16.1	16.4	16.7	17.0	17.3	17.7	18.0	18.4	18.8
12	19.2	19.6	20.0	20.4	20.8	21.2	21.6	22.0	22.5	23.0
13	23.4	23.8	24.2	24.6	25.0	25.4	25.8	26.2	26.6	27.0
14	27.4	27.9	28.5	29.0	29.6	30.1	30.7	31.3	31.9	32.5
15	33.1	33.6	34.2	34.7	35.3	35.8	36.4	36.9	37.5	38.0
16	38.6	39.3	39.9	40.6	41.2	41.9	42.6	43.3	43.9	44.6
17	45.0	45.7	46.4	47.1	47.8	48.5	49.2	49.9	50.6	51.3
18	52.1	52.8	53.6	54.3	55.9	55.8	56.6	57.3	58.1	58.8
19	59.4	60.0	60.7	61.3	62.0	62.6	63.3	64.0	64.6	65.3
20	66.0	66.6	67.3	67.9	68.6	69.2	69.9	70.5	71.2	71.9
21	72.8	73.6	74.5	75.3	76.2	77.0	77.9	78.7	79.6	80.5
22	81.6	82.5	83.4	84.3	85.2	86.1	87.0	87.9	88.8	89.7

[1]Based on Behre's form-class volume tables (1).

Table 19.--Ratio of merchantable volume to total volume of spruce and fir on dominant softwood sites, in percent

10-YEAR-OLD CUTTINGS

Density index	Composition index									
	10	20	30	40	50	60	70	80	90	100
10	21.5	26.5	30.4	33.4	36.5	39.2	41.5	43.6	45.5	47.5
30	26.0	29.5	33.1	36.0	38.8	41.1	43.2	45.1	47.2	49.1
50	30.8	32.8	35.8	38.3	40.8	42.9	44.9	46.9	48.9	50.5
70	32.1	35.2	38.0	40.4	42.6	44.7	46.6	48.5	50.2	51.7
90	34.8	37.7	40.1	42.2	44.3	46.3	48.2	49.9	51.4	52.7
110	37.0	39.8	41.9	43.9	45.9	48.0	49.7	51.2	52.5	53.6
130	39.4	41.5	43.6	45.7	47.7	49.5	51.0	52.3	53.4	54.7
150	41.2	43.4	45.3	47.2	49.2	50.8	52.1	53.2	54.5	55.6
170	43.0	45.0	47.0	48.9	50.5	51.9	53.1	54.3	55.5	56.5
190	44.8	46.9	48.6	50.3	51.7	52.9	54.1	55.3	56.4	57.4
210	46.5	48.2	50.0	51.5	52.7	53.9	55.1	56.2	57.2	58.2
230	48.0	49.9	51.3	52.5	53.8	55.0	56.0	57.1	58.1	59.0
250	49.6	51.1	52.3	53.6	54.8	55.9	56.9	58.0	58.9	59.8
20-YEAR-OLD CUTTINGS										
10	37.4	39.9	42.0	44.1	46.2	48.0	49.9	51.3	52.5	53.7
30	39.5	41.8	43.8	45.9	47.7	49.7	51.1	52.3	53.5	54.8
50	41.4	43.6	45.5	47.5	49.3	50.9	52.2	53.3	54.6	55.7
70	43.2	45.1	47.2	49.1	50.6	52.0	53.1	54.4	55.5	56.7
90	44.9	46.9	48.8	50.4	51.8	53.0	54.2	55.3	56.5	57.4
110	46.7	48.4	50.2	51.6	52.9	54.0	55.1	56.2	57.3	58.2
130	48.2	49.9	51.4	52.7	53.8	55.0	56.0	57.1	58.1	59.0
150	49.7	51.2	52.4	53.7	54.9	55.9	57.0	58.0	58.9	59.8
170	51.0	52.2	53.4	54.7	55.8	56.9	57.9	58.8	59.7	60.3
190	52.0	53.2	54.5	55.6	56.7	57.7	58.7	59.5	60.2	61.1
210	53.0	54.2	55.4	56.5	57.5	58.5	59.2	60.1	61.0	61.8
230	54.0	55.2	56.4	57.3	58.3	59.1	59.9	60.9	61.7	62.5
250	55.0	56.2	57.3	58.2	59.0	59.9	60.8	61.6	62.4	63.2
30-YEAR-OLD CUTTINGS										
10	46.8	48.6	50.3	51.7	52.8	54.0	55.2	56.2	57.3	58.3
30	48.3	50.0	51.5	52.7	53.8	55.1	56.1	57.2	58.1	59.1
50	49.9	51.2	52.5	53.7	54.9	56.0	57.0	58.1	59.0	59.9
70	51.1	52.2	53.5	54.7	55.9	56.9	57.9	58.9	59.8	60.4
90	52.1	53.2	54.6	55.7	56.8	57.8	58.7	59.6	60.4	61.2
110	53.1	54.3	55.6	56.6	57.6	58.6	59.3	60.3	61.1	61.9
130	54.1	55.3	56.4	57.4	58.5	59.2	60.1	61.0	61.8	62.6
150	55.1	56.2	57.2	58.3	59.1	60.0	60.8	61.7	62.5	63.2
170	56.0	57.1	58.1	59.0	59.9	60.7	61.5	62.4	63.2	64.1
190	57.0	58.0	58.9	59.8	60.5	61.3	62.2	63.1	63.9	64.4
210	57.9	58.7	59.7	60.4	61.2	62.0	62.9	63.8	64.4	65.1
230	58.8	59.4	60.2	61.0	61.9	62.8	63.6	64.3	65.1	65.5
250	59.3	60.1	61.0	61.8	62.7	63.5	64.1	65.0	65.5	66.0

(Continued)

Table 19, continued.--

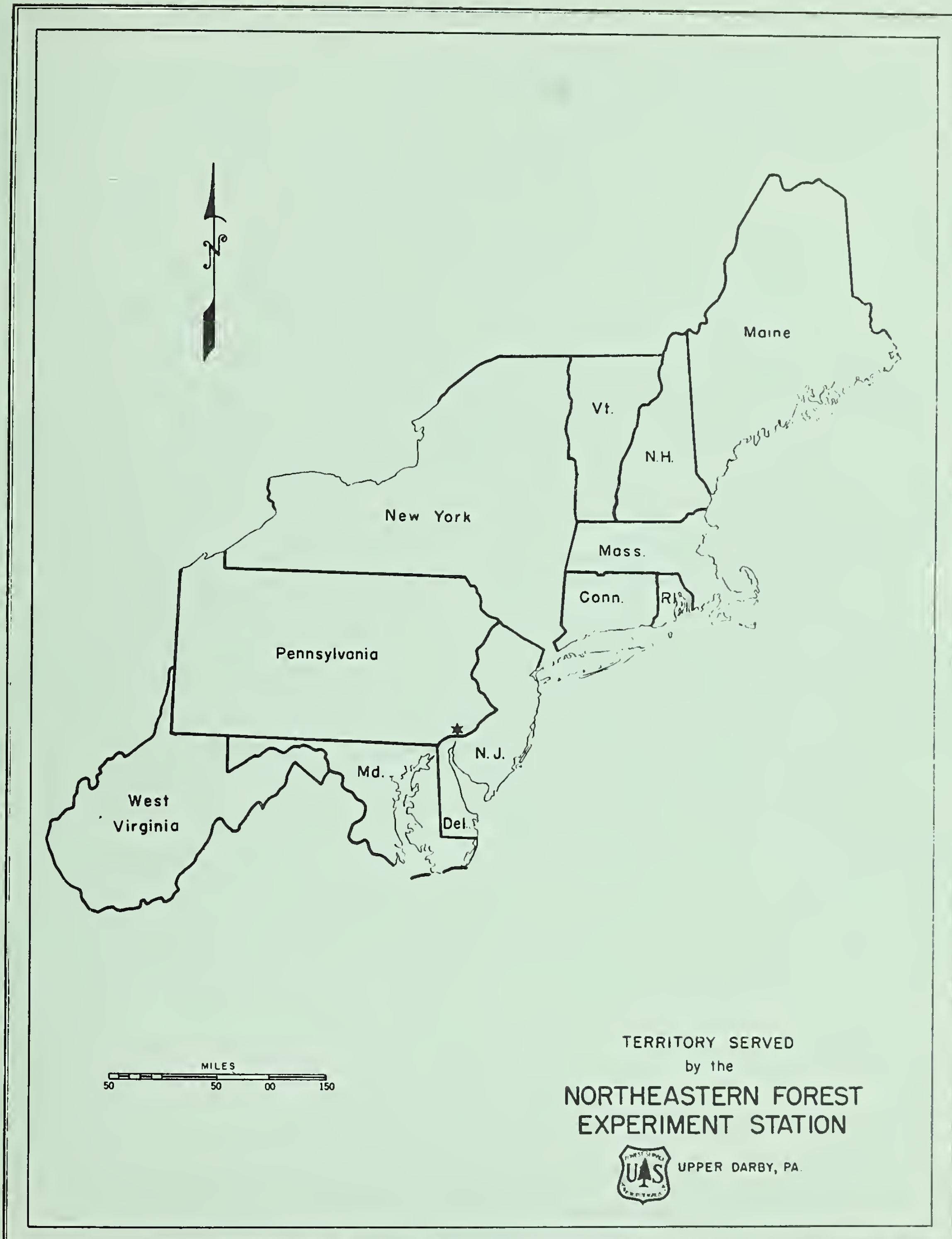
40-YEAR-OLD CUTTINGS

Density index	Composition index 10	20	30	40	50	60	70	80	90	100
10	53.1	54.5	55.6	56.7	57.7	58.6	59.5	60.3	61.2	61.9
30	54.2	55.4	56.4	57.5	58.4	59.3	60.2	61.0	61.8	62.6
50	55.2	56.2	57.3	58.3	59.2	60.1	60.9	61.7	62.5	63.3
70	56.0	57.2	58.2	59.0	60.0	60.8	61.6	62.4	63.2	63.9
90	57.0	58.1	58.9	59.8	60.6	61.4	62.3	63.1	63.8	64.6
110	57.9	58.8	59.7	60.4	61.3	62.1	63.0	63.7	64.4	65.2
130	58.7	59.5	60.3	61.2	62.0	62.9	63.6	64.3	65.1	65.7
150	59.4	60.2	61.1	61.8	62.8	63.4	64.2	65.0	65.6	66.2
170	60.1	61.0	61.7	62.7	63.3	64.1	64.9	65.5	66.1	66.7
190	60.9	61.6	62.4	63.2	64.0	64.8	65.4	66.0	66.6	67.3
210	61.5	62.3	63.1	63.9	64.7	65.3	65.9	66.4	67.2	67.7
230	62.2	63.1	63.9	64.5	65.2	65.8	66.4	67.1	67.6	68.3
250	63.0	63.9	64.4	65.1	65.6	66.3	67.0	67.5	68.2	68.8
50-YEAR-OLD CUTTINGS										
10	58.0	58.8	59.7	60.4	61.3	62.1	63.0	63.8	64.5	65.2
30	58.7	59.6	60.3	61.2	62.0	62.8	63.7	64.4	65.1	65.7
50	59.5	60.2	61.1	61.8	62.7	63.6	64.3	65.0	65.6	66.2
70	60.1	61.0	61.7	62.6	63.4	64.2	64.9	65.5	66.1	66.7
90	60.9	61.6	62.5	63.3	64.0	64.8	65.4	66.0	66.6	67.3
110	61.4	62.4	63.1	63.9	64.7	65.3	65.9	66.5	67.2	67.8
130	62.3	63.0	63.8	64.6	65.2	65.8	66.4	67.1	67.7	68.4
150	62.9	63.7	64.5	65.1	65.7	66.3	67.0	67.6	68.3	68.8
170	63.6	64.4	65.0	65.6	66.2	66.9	67.5	68.2	68.7	69.4
190	64.3	64.9	65.5	66.1	66.8	67.4	68.1	68.6	69.3	69.9
210	64.8	65.4	66.0	66.7	67.3	68.0	68.5	69.2	69.8	70.2
230	65.3	65.9	66.5	67.2	67.8	68.4	69.1	69.7	70.1	70.9
250	65.8	66.4	67.1	67.7	68.3	69.0	69.5	70.1	70.7	71.2
60-YEAR-OLD CUTTINGS										
10	61.6	62.5	63.2	64.0	64.7	65.4	66.0	66.6	67.2	67.8
30	62.3	63.1	63.9	64.6	65.3	65.9	66.5	67.1	67.8	68.3
50	63.0	63.8	64.5	65.2	65.8	66.4	67.0	67.7	68.3	68.8
70	63.7	64.4	65.1	65.7	66.3	66.9	67.6	68.2	68.8	69.3
90	64.3	65.0	65.6	66.2	66.8	67.5	68.1	68.7	69.3	69.9
110	64.9	65.5	66.1	66.7	67.4	68.0	68.6	69.2	69.8	70.3
130	65.4	66.0	66.6	67.3	67.9	68.5	69.1	69.7	70.2	70.8
150	65.9	66.5	67.2	67.8	68.4	69.1	69.6	70.1	70.8	71.2
170	66.4	67.1	67.7	68.3	69.0	69.5	70.1	70.7	71.1	71.6
190	67.0	67.6	68.2	68.9	69.4	70.0	70.6	71.1	71.5	71.9
210	67.5	68.1	68.8	69.3	70.0	70.5	71.0	71.5	71.9	72.2
230	68.0	68.7	69.2	69.9	70.4	70.9	71.4	71.9	72.1	72.6
250	68.6	69.1	69.8	70.3	70.8	71.3	71.8	72.1	72.5	73.0

Table 20.--Ratio of merchantable volume to total volume of spruce and fir on secondary softwood sites, in percent

10-YEAR-OLD CUTTINGS

Density index	Composition index								
	10	20	30	40	50	60	70	80	90
10	21.4	28.4	31.2	34.7	35.2	35.9	36.4	36.2	36.6
20	24.4	30.0	33.3	36.8	37.1	37.8	38.2	37.9	38.4
30	25.5	31.2	35.7	38.5	39.4	39.9	39.6	40.0	40.4
40	27.9	33.6	37.1	40.5	41.5	42.0	41.7	42.0	42.4
50	29.6	34.7	39.4	42.5	43.3	43.7	44.0	43.8	44.0
60	31.9	36.8	41.2	44.4	45.4	45.7	45.7	46.0	46.2
70	33.6	39.1	43.3	46.3	47.3	48.0	48.0	48.3	48.1
80	34.7	41.0	45.1	48.5	49.6	49.8	50.0	50.2	50.4
90	37.2	42.6	47.3	50.8	52.2	52.5	52.7	53.0	52.8
100	38.8	45.0	49.8	53.3	55.2	55.6	55.8	55.9	56.2
110	40.7	46.8	52.0	56.6	58.4	58.6	59.0	59.2	59.5
120	42.9	49.2	55.0	60.3	62.6	63.1	63.9	64.0	64.2
130	44.8	51.5	58.4	64.6	66.6	67.2	67.6	67.7	68.0
140	47.3	54.2	62.6	68.2	69.9	70.2	70.5	70.7	70.7
150	49.4	57.4	66.7	71.0	72.0	72.2	72.5	72.4	72.5
20-YEAR-OLD CUTTINGS									
10	29.5	34.7	39.1	41.7	42.9	43.0	43.3	43.6	43.4
20	30.8	36.8	41.0	43.8	44.8	45.3	45.4	45.6	45.4
30	32.7	38.5	42.6	45.9	46.6	47.3	47.3	47.6	47.8
40	34.7	40.5	45.0	47.8	49.2	49.4	49.6	49.8	50.0
50	36.8	42.5	46.6	50.4	51.3	51.7	52.0	52.4	52.5
60	38.5	44.4	49.2	52.9	54.4	54.8	55.2	55.2	55.4
70	40.5	46.3	51.3	55.8	57.4	57.8	58.2	58.4	58.6
80	42.2	48.3	54.4	58.9	61.2	62.0	62.6	62.8	63.0
90	44.7	50.6	57.4	63.6	65.8	66.2	66.7	66.9	67.0
100	46.5	53.3	61.0	67.5	69.2	69.7	69.8	69.9	70.1
110	48.5	56.7	65.8	70.4	71.6	71.7	72.0	72.0	72.1
120	50.8	60.1	69.1	72.3	73.0	73.3	73.5	73.5	73.6
130	53.5	64.5	71.5	73.7	74.4	74.5	74.6	74.7	74.7
140	56.6	68.2	73.0	74.9	75.4	75.6	75.7	75.7	75.8
150	60.3	71.0	74.4	75.9	76.2	76.4	76.5	76.6	76.6
30-YEAR-OLD CUTTINGS									
10	36.4	42.0	46.0	49.8	50.8	51.1	51.5	51.5	51.9
20	38.2	43.8	48.3	52.2	53.6	54.1	54.4	54.5	54.8
30	39.6	45.9	50.8	55.0	56.5	57.1	57.5	57.6	57.9
40	41.7	48.0	53.5	58.4	60.1	60.9	61.2	61.5	61.7
50	43.8	50.2	56.6	62.6	64.6	65.2	65.7	65.9	66.0
60	45.7	52.5	60.1	66.7	68.2	68.8	69.2	69.4	69.6
70	48.0	55.7	64.5	69.7	71.0	71.4	71.5	71.6	71.6
80	50.4	59.1	68.3	71.9	72.8	72.8	73.0	73.1	73.2
90	52.5	63.6	70.9	73.4	74.1	74.2	74.4	74.3	74.4
100	55.7	67.3	72.7	74.6	75.1	75.3	75.4	75.4	75.5
110	59.1	73.4	74.1	75.6	76.1	76.2	76.2	76.4	76.4
120	63.6	72.3	75.1	76.5	77.0	77.1	77.2	77.2	77.5
130	67.7	73.7	76.1	77.4	77.7	77.7	77.9	78.0	78.0
140	70.7	74.8	77.0	78.1	78.4	78.5	78.6	78.6	78.7
150	72.5	75.9	77.7	78.7	79.1	79.1	79.2	79.2	79.2
40-YEAR-OLD CUTTINGS									
10	43.3	49.8	55.7	61.2	63.7	64.3	64.6	64.9	65.2
20	45.6	52.2	59.1	65.7	67.6	68.1	68.4	68.7	68.8
30	47.6	55.0	63.7	69.2	70.5	70.8	71.1	71.3	71.3
40	49.6	58.4	67.8	71.6	72.5	72.6	72.8	72.9	72.9
50	52.0	62.6	70.5	73.1	73.8	74.1	74.2	74.2	74.2
60	55.2	66.8	72.5	74.4	74.8	75.0	75.1	75.2	75.3
70	58.3	70.0	73.8	75.4	76.0	76.0	76.1	76.2	76.2
80	62.8	72.0	74.8	76.2	76.8	76.9	77.0	77.0	77.1
90	67.0	73.4	76.0	77.2	77.6	77.7	77.8	77.8	77.7
100	70.0	74.7	76.8	77.9	78.3	78.4	78.4	78.5	78.5
110	72.1	75.7	77.6	78.6	78.9	79.0	79.1	79.1	79.1
120	73.5	76.6	78.3	79.2	79.6	79.6	79.7	79.7	79.7
130	74.7	77.4	78.9	79.8	80.0	80.1	80.1	80.2	80.2
140	75.8	78.1	79.6	80.3	80.6	80.6	80.7	80.7	80.7
150	76.7	78.8	80.1	80.8	81.1	81.1	81.1	81.1	81.2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